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FOR
TURKISH NAVY

by

Fikrettin Emanet

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Thesis Advisor Fenn Horton

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But national security also depend upon economic factors, which are variously interpreted and defined. Most writers who stress the importance of economic factors are referring to the economic strength of the nation, as contrasted with its military forces.

When a country like Turkey, which has one of the most important strategic location in the middle east, is trying to accomplish its defense objectives as a NATO allied country with limited resources, it must use these resources as effectively as possible in order to select defense systems. The aim of this paper is to select the best force structure by using cost-benefit analysis. Each candidate force structure includes a different type of new frigate for the Turkish Destroyer Fleet.

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Cost Benefit Analysis for Turkish Navy

by

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Submitted in partial fulfillment of the
requirements for the degree of

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I. INTRODUCTION

Turkey is one of a number of smaller nations which possesses relatively poor, unsophisticated industrial base. It doesn't have sufficient resources to undertake the necessary research, development and production required to satisfy its own defense needs. History shows that Turkey has preferred to purchase a substantial proportion of its defense requirements from industrialized friendly nations, especially U.S. and West Germany.

On February 1975, The United States enacted an arms embargo on Turkey in response to the Turkish invasion of Cyprus in 1974. During the embargo Turkish armed forces lost many of their operational capabilities due to lack of spare parts and industrial support. Almost all the defense systems which were purchased from the United States were in poor condition at the beginning of 1980s.

After 1981, Turkish Government decided to modernize the defense systems which were possessed by the armed forces by taking into account the experience which were won from the past defense equipment and system acquisitions.

In November 1985, the Defense Development and Support Administration (DIDA) was established by the Turkish Government, and large amounts of financial resources were created for the acquisition of defense systems. At the end of 1985 Turkish Naval Forces decided to modernize its destroyer/frigate fleet by using these financial resources.

Turkish industry doesn't have sufficient technology to undertake the necessary research, development, production and life cycle support required to design and construct new type destroyer/frigate. In addition, the demand for the destroyer/frigate by the Turkish Navy is not enough to design a new type. So, the best way is to acquire some amount of destroyers/frigates which are designed, constructed and deployed by the other industrialized friendly nations.

The acquisition of a new system needs a policy. Policy usually includes;

- The requirement; to express needs in mission terms
- The requirement for agency head approval at key decision points (milestones), if system is newly developed.
- The requirement, that all goods and services be acquired on a competitive basis to the maximum extent possible, in order to maximize innovation and minimize cost.

- Consideration of life cycle cost, schedule and logistic supportability.
- Establishment of clear lines of authority, responsibility and accountability for the management of programs.

[Ref. 1: p. 5]

In this paper we will express the mission requirements and consideration of life cycle cost for a competitive force structure and we will choose the best force structure for the Turkish Destroyer Fleet.

II. TURKISH NAVY CASE

A. MISSION AREA ANALYSIS

A naval operation , taken into broad sense, begins at the stage where the opponents are more or less ignorant of their relative position. Whoever takes the offensive will be anxious to keep his initial strategic moves secret so as to retain freedom of action and, if possible, achieve surprise when the time for action comes. The defender is equally anxious to locate the enemy, or at least find out roughly where he is, as soon as possible and to gauge his intentions. This first stage is over when the mutually unknown quantities are revealed. Stage two in the scheme of things consist of preparing for ultimate action the enemy must be precisely located and all necessary steps must be taken in preparation for action. The third and last stage is that of action itself, and the ultimate and most significant event in any operation is , of course battle.

At stage one, the strategic approach phase could last for months. Today the means of search are direct optical detection, maritime patrol aircraft with its large radius action, ship mounted sensors, satillates, and fixed underwater ground acoustic arrays.

In the second phase of naval operations, the forces involved will be preparing themselves for ultimate action. At the point where this stage begins, it is assumed that at least one of the opponents has some operational intelligence about the other. More precise information is now needed about the situation in the prospective area of action. What vessels are present in the area? What type are there? Are they friendly, neutral or enemy? How are they formed up? What are they doing? What might their intentions be? It is then necessary to detect, locate, identify and analyze the behavior of the contacts in order to establish a complete pattern of tactical data.

Looking at the principal sensors, we will first consider those that work above the surface, begining with the radar. Radar achieved its theoretical maximum range early on, in terms of accessibility of the target, the power is emitted and wave lengths used. It is possible to deal with several targets and several weapons simultaneously if the equipment includes electronic scanning. There have also been improvements in discrimination (the ability to cope with interference, whether due to natural causes or caused by the enemy e.g Chaff) and in making radar transmissions rather more difficult to detect.

The passive detection of transmissions over a wider and wider wave band has itself made great progress, from radio frequencies, including radar and thermal emissions. Passive detection methods are themselves undetectable but they are dependent on the enemy making detectable transmissions. During second stage passive detection methods may be inadequate. All these sensors, to which must be added to the irreplaceable human eye-brain combination, can be carried by ships or patrol aircraft.

In the silent world below the surface, although sonar has made great strides, it still offers limited chance of detecting a submarine that wants to avoid it. Passive listening is making headway largely against noisy submarines, while magnetic anomaly detection equipment is able to relocate an enemy only at very short range.

The final phase of the operations is battle. At this stage the sensors continue their work in much the same way as before, but the weapons must now go into the action.

Traditional arms (guns, torpedoes and ahead throwing antisubmarine weapons) have been the subject of continual improvement. Modern gunnery control methods using computers have given fresh life to gunnery by making it considerably more accurate and greatly increasing the speed with which guns can be brought into action, that can be entirely automatic from first detection to cease-fire. Multi-barrel small calibre guns with a very high rate of fire and heavy shells are promising new types of traditional gunnery for small, close range targets. In association with modern radar, this kind weapon could effectively engage certain types of missiles, even at very short notice.

Ahead throwing antisubmarine weapons (mainly rockets) are giving ground to torpedoes but are still attractive by reason of their comparatively low cost, their suitability for small ships and their improved range. Torpedoes have great advantage of hitting under water, they strike the most sensitive area of target, whose first need is to stay afloat, and they benefit from the damping effect of the sea itself which increases the effect of an explosion underwater.

These advances in traditional weapons are important and in many cases allow them to keep a place alongside their more modern counterparts.

Missiles are obviously at the top of the new weapon list. At the tactical level the many kinds of missiles in service have to be distinguished by their purposes. Surface to surface missiles are so quite light weight and most significantly, a small ship can carry a destructive power greater than that of gunnery.

Various types of missiles in use against aircraft have radically changed the nature of fighting between ships and aircraft. In some instances, an attacking aircraft can be engaged even before it has a clear view of the situation itself with a high chance of hitting. However, with conventional radar where data rate is limited, the number of targets saturated if an attacker is prepared to pay the price.

Defensive or offensive weapon system equipped with modern scanning radar is capable of dealing with several enemy targets and guiding a number of missiles simultaneously, the situation is entirely different. Faced with the threat of effective reaction from the ship under attack, whether or not it has a high performance antiaircraft missile system, an assailant is likely to stand off and launch an air to surface missile himself.

Weapon systems must include all the possibilities of active electronic warfare, that is to say, to whole array of decoys and jammers which, while not killers in themselves, are handled rather like defensive weapons. Blinding enemy sensors with false targets or transmissions that saturate the frequencies (presenting the incoming missiles with baits on which they will home more readily than their genuine targets) these are all methods of destroying the enemy homing missile systems. From these stems the needs for opposing all these counter measures (ECM) by Counter-Counter measures (ECCM) which may be either of the same kind themselves or, a change to a totally different system enabling detection, guidance and terminal homing to be effected without transmitting, by using instead, the various enemy emissions of radar, infra-red thermal or light rays.

In summary, the forces which could fight at sea today or in the near future appear to be distinguished by the following important developments;

- All the actors in naval warfare today would approach the scene of combat already engaged in a complex preliminary manoeuvre in which numerous methods of collecting intelligence are set against the methods for confusing or decisiveing them in various ways. The technical and intellectual mastery of these phase of naval action is becoming essential to success in combat.
- Fighting itself would be radically changed by the ubiquity of the threat of attack, which could come at any moment from near or far, from the sky or sea surface, or from underwater all in the shape of missiles of higher and higher performance and more and more varied capabilities, and one day, doubtless in the shape of even more futuristic weapons.

1. **Geographical location of Turkey**

An overview of the geographic location and position of the Turkey will help a great deal toward the firm understanding of the problems related to one of the Worlds most historic lands and water groups.

The sea on the southern part of the Turkey is Mediterranean sea and the coastal length is 1250 km. There is little information on the shelf depths around the eastern Mediterranean, possibly because of the frequent variation in depths. Along the Turkish coast from the Rhodos channel eastward to Galidonya Burun there is no significant continental shelf. From Galidonya Burun to Northeastern corner of the Antalya bay the average width is 4.5 km. Along this shelf the depth varies from 40 meters to 130 meters. Off the gulf of Iskenderun a composite delta of several rivers has built a shelf 70 km. wide. The shelf break is about 300 m deep along this portion of the shelf. The shelf is very narrow or absent at the Turkish-Syrian border. Along the southern coast of Turkey the continental slope has a gradient range from 1/24 to 1/10. The slope is modified in the Gulf of Iskenderun by sediments from the adjacent rivers.

The sea on the western coast of Turkey is Aegean and the length of Turkey's Aegean coast is 2805 km from Fethiye Bay to Saros Bay.From the frontier of Greece to Dardannelles straits the Saros Bay banks extends, the depth of the sea varies from 0 to 25 meters. The depth of the sea from Dardannelles to Izmir (Smyrna) shows the same properties. Along the coast its depth is usually between 2 to 15 meters. The depth of the sea is available to all kind vessel along the coast between Izmir to Fethiye Bay.

There are more than 200 islands in the Aegean sea which belong to Greece and most of them very close to Anatolia. The width of some of the important waterways between these islands and Anatolia is 1.5 km near the Samos, 4 km near the Kos. The height of these islands average more than 1000 meters. 2148 m at Crete, 1215 m at Scarpanto, 1160 m at Samos and 1297 m at Khios islands. The Greek islands in the Aegean sea are available as shelter for enemy warships.

The weather condition is a major problem for operating the vessels on the Aegean sea. The southern and southeastern winds effects all kind of transportation and operation. Statistically more than 200 days a year the sea condition is over 4. This is another constraint for the size of vessels which will operate on the Aegean sea.

The Turkish straits unite the Mediterranean sea, which can be considered a branch of the Atlantic Ocean and which expands eastward from Gibraltar and cuts about 2330 miles deep into the triple continent, with the Black sea, which itself is a vast alcove of the Mediterranean.

This waterway separates the continents of Asia and Europe from each other, and this divides Turkey into two natural sections.

- The European section: This is a "wedge shaped" segment of the Balkan peninsula and lies east of the Meric river, and has frontage on the Aegean sea, the straits and the Black sea. This section is commonly known as Trakya.
- The Asiatic section: This is a large peninsula with a kind of Rectangular shape which reaches towards Europe between the eastern Mediterranean basin and the Black sea. This part of the Turkey commonly known as Anatolia.

Whenever mentioned in international law, the term "Turkish straits" legally includes the three geographical distinct sections, the Dardannelles, the sea of Marmara and the Bosphorus, which collectively make up the narrow but highly strategic waterway which is a link of about 378 km in length between the almost land locked Black sea and Mediterranean.

Dardannelles: The length of the Dardannelles is about 72 km. Its width varies from 8.1 km at the Aegean externetiy to 1400 meters at the narrowest part. The rolling hills with relatively low banks are of a brownish grey color wherever they are not covered by the maquis and other species of Mediterranean vegetation. The depth varies from 50 to 100 meters. As the Aegean Sea and the Sea of Marmara are considerably deeper, the Dardannelles form a kind of under water plateau between the two seas. The two main flows of the complicated current systems are

- A strong surface current from Black sea to Aegean sea
- A deeper under water current from Aegean sea to Black sea

At the narrows of Dardannelles and nearly points the surface current acquires a speed which sometimes reaches 5 miles per hour. Most of the sailing vessels without strong enough engines, when going up the current, need towing, especially in the weather with northerly or northeasterly winds

The Sea of Marmara: This small inland sea which was known as Propontis in the classical age has an area of 14500 square km. It is connected with the Black Sea through the Bosphorus and to the Aegean through the Dardannelles. The length of the sea is 306 km, its extreme width is about 90 km. Most of the small bays are really shallow. With the exception of days with very strong southerly (Lodos) or northerly (Poyraz) winds, navigation is easy.

Bosphorus: The length of the straits is about 18 miles. Its depth varies from 30 to 80 meters and it reaches its maximum depth at the narrowest point where the erosion of the currents is the greatest.The width of the Bosphorus varies from 570 meters at the narrowest point to 3.6 km at the largest point.

The Bosphorus has no sandbars and very few beaches, the shores are for the most part elevated and the rolling hills reach the shores at a rather step angle. The system of currents in the Bosphorus is similar to the one in Dardannelles. On some spots the currents are so strong that they form whirlpools and are called "Devil's current". The erosive action of these currents is tremendous. Navigation is often difficult toward to the entrance to the Black sea because of lack of physical barriers against the northwest winds and northeast winds. [Ref. 2: p. 10]

2. The Potential Enemies and Their Naval Forces

In this geographical region the possible enemies of the Turkey are U.S.S.R, Syria and Greece. Small information about their naval forces on the Black sea and Mediterranean sea will help us to understand which operational capability is required for the Turkish Navy.

The Soviet Union has embarked on a maritime strategy designed to help it break out of its long history of continental confinement. This policy means, in the first instance, attempts to control the Baltic sea, the Black sea and ultimately the Mediterranean. Simultaneously, the Soviet Union is probably striving to become the dominant power in such vital straits as the Bosphorus and Dardannelles, through which its fleets must pass to reach the high seas.

Beyond these goals, the Soviets want to gain dominant influence at several major junctions of the world's seaways. Specifically, they have their sights on the Suez canal, and strait of Gibraltar. In pursuit of these ends, the Soviets would most likely try systematically to limit and eventually to stop noncommunist naval operations in areas they consider strategically critical to their plans.

The Red Banner Black sea fleet is responsible for operations in the Black sea and, more significantly, it provides surface warships and aircraft for operations in the Mediterranean sea as the fifth Eskadra (Task Force). However, the Black sea fleet doesn't provide submarines for Mediterranean operations. The Black sea is essentially a "Soviet Lake" with Turkey the only potentially hostile nation bordering the sea.

After World War Two the shipyards in the Black sea region were rapidly rehabilated to help to rebuild the Soviet fleet. The formation of NATO in 1949 with Turkey and Greece successfully resisting communist takeover seemed to deny the Black sea fleet easy access to the Mediterranean through the Turkish straits. Still, in 1958 the Soviets first deployed naval forces in to the Mediterranean. These were submarines that in 1960 were based, with a tender, at Vlore, Albania. The following year the Soviets

were forced to abandon Vlore, leaving behind two Whiskey class submarines seized by Albanians. The loss of this base pointed up the limitation of Soviet naval logistics and Soviet combatant forces were not again deployed on a sustained bases to the Mediterranean until 1964.

From the mid 1960s onward Soviet naval forces have operated continuously in the Mediterranean, with surface ships and aircraft coming from the Black sea and submarines from the Northern Fleet. By the early 1970s the Soviets had an average daily strength of 50 or more naval units in the Mediterranean on a regular basis. This force, the Fifth Eskadra, reached a peak strength of some 60 surface ships and 25 submarines during the October 1973 confrontation with the U.S in the Yom Kippur war in the Middle East. Effort to obtain support bases for the Soviet Mediterranean squadron have centered on Egypt (until they were ejected in 1973) and Syria. The typical composition of the Fifth Eskadra is:

- 6 - 8 Torpedo attack submarines
- 1 - 2 Cruise missile attack submarines
- 1 - 2 Missile cruisers
- 6 - 8 Destroyers and Frigates
- 1 - 3 Mine sweepers
- 1 - 3 Amphibious ships
- 15 - 20 Auxiliary ships
- 5 - 6 Survey research and intelligence collection ships

Soviet combat operations in the Black sea and Mediterranean would be supported by land based naval aircraft from bases in Crimea. In addition cruiser-helicopter carriers of the Moskova class are based in the Black sea and operate regularly in the Mediterranean as do the Kiev class aircraft carriers when they are in the Black sea area. The Black sea fleet also has the largest cruiser/destroyer force of any of the Soviet fleets. In total, the Black sea fleet has 27 percent of the navy's major combatants (frigates and above) but only 7 percent of the Navy's submarines (with no nuclear or ballistic missile units) including the Caspian flotilla. The Black sea fleet has 25 percent of the Navy's aircraft and 22 percent of the personnel.

The country on the west the neighbor and NATO Alliy is Greece. The violent manifestation of Greek nationalism in Cyprus in 1955, the beginning of a new generation-long crisis between Greece and Turkey. The Cyprus crisis in 1974 again tested mutual obligations and responsibilities. The purpose of Turkish military

intervention in July, justified by Turkey's obligation under the 1960 Treaty of guarantee, was to protect the Turkish minority from the "Hellenic Republic of Cyprus" which was led by an international terrorist, installed by a coup, backed by military dictatorship in Athens, and bent on union with Greece.

As Wictor Papacosma observes, Greece appears to struggle with its NATO partners more vigorously than with the Soviet antagonist. On the one hand, there is the continuing conflict with Turkey that centers on the future of Cyprus. Disputes continue over operational control, territorial waters, and airspace rights in the Aegean. [Ref. 2: p. 11]

On the south, the neighbor of Turkey is Syria which has coast along the Eastern Mediterranean sea has potential hostility against Turkey. In the past two countries had a lot of problem and for which they couldn't find any solution. After 1960s Syria has strong relationship with USSR and most of the naval vessels were bought from USSR. Today Syrian navy has:

- 3 submarines (2 Ex Soviet Romeo, 1 Ex Soviet Whiskey class)
- 2 Frigates (Ex Soviet "Petya II" Class
- 3 Ex Soviet "Plonochny B" Class amphibious ships.
- 22 Fast Attack Craft-Missile boat (Ex Soviet OSA I, OSA II, Comar classes) which are equipped with SSM; 4SS-N-2
- 8 Fast Attack-Torpedo (Ex Soviet "P-4") Class

During the active war, it is obvious that Turkish navy can't operate against the USSR navy which one of the most advanced navies in the world, in open sea like Black sea or Mediterranean by itself. In reality the NATO war plans shows that other allied navies will operate together against the Warsaw pact navies. But in the short term, a small navy, by using speed and geographical advantage may give big damage to enemy vessels. The most available waterway and seas are the Turkish straits and Aegean sea for this kind operation. So when we select the type of destroyer/frigate which candidate for Turkish Navy, we will take into account the geographical position of straits and Aegean sea and their limitations on the characterestics of the destroyer/frigate.

B. PRESENT CAPABILITIES OF THE TURKISH DESTROYER FLEET

The primary source of the Turkish destroyer fleet is the United States. During the 1960s and 1970s the U.S sold and leased its surplus destroyers which were built during the World War II to Turkey. Today the Turkish Navy has 8 Ex- U.S Gearing, 2 Ex-

Fletcher, 2 Ex- Carpenter, 1 Ex- U.S Allen M Sumner, 1 Ex- U.S Robert H Smith classes destroyers and 2 Koln-West German, 2 Berk-Turkish classes frigates.

These destroyers were purchased from the United States under priced. U.S sold them at scrap value instead of the higher market value. For example; the Mc Kean (DD 784) was sold for S 357,410 when its market value was S 1,133,443. Additionally the conversion cost, administrative cost and fuel weren't included when the Mc Kean pricing.

Four destroyers were leased from the United States in better condition. When they leased DD 822 had S 8,500,000, DD 842 had S 7,900,000, DD 825 had S 7,900,000 and DD 827 had S 3,321,000 market value, but they were leased without lease payment. [Ref. 3: p. 3]

The present type destroyers and their charecterestics are:

1. **Gearing Class**

These destroyers were built just after the World War II, between 1945-1946 by the U.S naval shipyards. During the 1950s they were modified, electronic and ASW capabilities were improved by the U.S shipyards. After 1973 eight destroyer were transferred/leased to Turkish Navy.

During the Cyprus invasion, Turkish Navy realized that the destroyers doesn't have enough electronic warfare, communication capability and air defense system. Between 1976-1985 these destroyers were equipped 40 mm orligon, 35 mm oerlikon with sapan fire control system.

In 1986, two destroyer were equipped with Harpoon guided missile system by the Turkish Naval Shipyard. Today there are small variations between the capabilities of these destroyers, but main characterestics are:

- Steam propalsion system, 33 knots max speed, 5800 miles max range at 15 knot speed.
- 5"/38" gun with GFCS Mk 37 fire control system, 35 mm oerlikon with sapan fire control system.
- ASROC-8 tube launcher, 2 triple Mk 42 torpedo tubes, AN/SQS 23 sonar as ASW weapon and systems.
- AN/SPS 40 long range air search radar, AN/SPS 10 surface radar, Decca navigation radar

Annual operation cost of each Gearing class destroyer is approximately S 3,300,000. The highest proportion of the cost is maintenance cost, because of the age

of these destroyers. The response time of the main propulsion system is too long, in normal condition 4 hours and in emergency situation 2 hours. The response time of the fire control system is not sufficient to defend the ship against advanced surface to surface missiles, air to surface missiles and jet fighters. But the shipyards have large experience with these ships and ship systems, and so maintenance is easy.

2. **Carpenter Class Destroyers**

Two destroyers were laid down in October 1945 and commissioned by the U.S Navy in November 1949. USS Robert A Owens (DD 827) were transferred in 1981 and USS Carpenter (DD 825) were transferred in 1982 to Turkish Navy. In 1984 both of them were equipped with 3″/50″ and 35 mm oerlikon gun with SPG 35 and Sapan II fire control system. In 1987 Turkish Naval shipyard decided to modernize these destroyers with VLS Seasparrow air defense missile and STIR radar. The charesterestics of these destroyers are:

- Steam turbine main propulsion system, 33 knot maximum speed and 5800 miles maximum range at 15 knot speed without refueling.
- 2-5″/38″ Mk 38 gun with Mk 56 fire control system, 2-3″/50″ gun with Mk 114 fire control system, and 35 mm oerlikon gun with Sapan fire control system.
- ASROC 8-tube launcher, 2 triple Mk 32 torpedo tubes, AN/SQS 23 sonar as ASW weapons and systems.
- AN SPS 40 long range air search radar, SPS 10 surface radar and Decca navigation radar.

Annual operating cost as the same Gearing class destroyers. But modernization cost is high for Seasparrow, STIR radar and 35 mm Oerlikon gun. Total modernization cost is approximately $ 21,092,000for each destroyer. Still communication systems are insufficient, ECM and ECCM capabilities doesn't exist or are in poor condition. The economic life of the systems which will be mounted to these destroyers is about 25 years, but the economic life of these destroyers are less than 10 years. They are already 38 year old, and this differance causes increased annual operating cost.

3. **Koln Class Frigates**

Two frigate were constructed in October 1959 by the H.C Stulcken-West Germany, and commissioned by the West German Navy in 1962. Both frigates were transferred to Turkish naval forces in 1983. The characterestics of these frigates are:

- Gas turbine main propulsion system, 28 knot maximum speed and 920 mile maximum range at 28 knot speed.

- 2-100 mm gun with M 45 fire control system, 6-40 mm guns with two M 45 fire control system.
- 4-28″ AS torpedo tubes, 80 mines and PAE/CWE M/F hull mounted sonar as ASW weapon and weapon systems.
- Surface and air search radar, DA 102 target designator radar.

The maintenance of the main propulsion system of these frigates are a big problem for the Turkish shipyards, because none of the shipyards have gas turbine overhaul capability. Another problem with these frigates is ventilation systems. These frigates were designed for the northern seas. The climate of the Mediterranean sea and Aegean sea is too warm for these frigates and during the summer months most of the electronic devices are off because of the cooling problem. The range of the long range air search radar is not enough (120 km) to detect the enemy targets in open sea, like Black Sea and Mediterranean Sea. They don't have any active guided surface-to-surface, surface-to-air missile system. Annual operating cost of these frigates approximately $ 3,100,000 .

4. **Berk Class Frigates**

First major warships which were built in Turkey in 1971, and were commissioned in 1973 (TCG Berk), 1975 (TCG Peyk). Main propulsion systems were purchased from Italy and almost all the electronic equipments and weapon systems were purchased from the United States. Main characterestics of these frigates are:

- Diesel engine main propulsion system, 25 knot maximum speed, 2500 mile maximum range at 18 knot speed.
- 4-3″/50″ gun with GFCS Mk 63 fire control system
- 2 triple Mk 32 AS torpedo tubes, 2 Mk 11 hedgogs and AN-SQS 29 series sonar as ASW weapon and systems.
- AN-SPS 40 long range air search radar, AN-SPS 10 surface radar and AN-SPG 34 fire control radar.

Annual operating cost of each Berk class frigates are $ 3,153,000. The maintenance of these frigates aren't easy since the lack of spare parts of main propulsion and main electric power systems. [Ref. 4: p. 524]

III. SOURCE SELECTION

A. PROBABLE SOURCE

The structures today's navies, have evaluated largely from the historical needs of individual nations to counter threats to their security and to protect their lifelines of maritime trade. The situation today is no different. NATO is a maritime community with its member nations not only linked together by the sea but globally with a dependence upon its free use, and it is this dependence which underpins the missions of our maritime forces;

- to deter aggression, through presence and visible projection of power
- to protect maritime trade and sea lines of communication
- to ensure the safe and timely arrival of reinforcements and resupply shipping
- to fight in response to aggression to achieve sea control and denial.

To meet these competing and demanding roles, balanced and capable naval forces are required, ranging from strike carriers through submarines to maritime patrol aircraft. But the vital and multipurpose component of all major navies has been and remains, the escort.

For any new class of multi role escort, it takes some 10 years from initial concept to operational status. It is therefore not surprising that even for the 1990s the dice are already cast, and a quick survey of some national and NATO plans shows that no significant change in approach to the escort question could be achieved much before the end of the next decade. Some examples of escorts under design or construction for service in 1990s are as follows:

- United States. Arleight Burke destroyers
- United Kingdom. Type 23 frigates
- Canada. Patrol Frigate Programme
- Germany. Type 122 frigates
- Italiy. Animoso class destroyers
- Netherland. M class frigates
- NATO. Nato Frigate Replacement Programme

These programmes are essentially only linear projections of previous classes with updated equipment. Even the multinational project of the NATO Frigate Replacement

Programme (NFR 90) falls into the linear projection category. The ships as currently envisaged are a logical progression of a mix of earlier designs, with state of the art sensors and weapons.

Collaborating offers the most cost effective-way of producing ships and weapon systems for the future, if correctly managed. In this respect the NATO Frigate Replacement Programme is the outstanding example so far. In theory anyway, the bigger the production run, the smaller the unit production cost.

The NATO Project Management Office (PMO) considered that the savings would be of the order of 15-25 per cent when compared to individual national procurement. Compromiser had to be reached but the conclusion was that some 80 per cent of the various different equipments required by the individual nations could be accommodated. NATO officals believe that some 50 frigates will be built at a cost of between $200 million to $300 million each. Since the project will remain open to other NATO nations, the number could grow in due course.

The aim is to design a common hull in which the required subsystems, such as weapons, power units sensors and communications equipment would be accommodated in modular form. This would give considerable scope to the industries of participating nations with a great range of possible off-set agreements. There would also be considerable exchange of ideas, knowledge and technological background which would enhance the final result. [Ref. 5: p. 23]

B. DEFENSE AGREEMENTS OF TURKEY

The source of defense equipment for the Turkish Navy should be a NATO allied country. But the relationships between these allies show big differance. These relationships will be one of the key factors when selecting the type of vessel.The quick review of the international relationships in defense area will give us some of the basic factors for source selection.

1. Turkey-West Germany Defense Cooperation

German - Turkish cooperation in the area of defense is based on an eventful history of the German Turkish relations. In the 19.th century close cooperation was established between the German and Ottoman Empires. During the times of worldwide difficulties in the twenties many Germans found a second home in Turkey.

On the base of their traditional friendship, Germany and Turkey have had close trade relations for several decades. The Federal Republic of Germany is also the biggest single economic partner of Turkey with first place in Turkish exports and

second place in Turkish imports. In this context, another important factor of German-Turkish relations can not go unmentioned; Millions of Turks, together with their families, have lived and worked hard in Germany, thus contributing to the well functioning and development of West German economy over the last 25 years. Besides the frequently cited and so often proved German Turkish friendship, this integration of Turkey in Europe and the western alliance also gives added significance to her relations with the Federal Republic of Germany.

With the establishment of the Defense Industry Development and Support Administration (DIDA) in November 1985, the Turkish Government has shown that it wants to assist the domestic industry in the build up and modernization of production capacities for armaments. Technical assistance for the modernization of the Turkish shipyards in Golcuk and Taskizak can testify to many years of successful cooperation with German industrial firms for the benefit of the Turkish Forces.

The value of defense aid which is provided in slices (with a volume of the current slice of 130 million DM, of which 80 per cent is used for the procurement of new material, while 20 per cent consist of surplus material of the German Armed Forces) has so far reached an overall volume of the 1450 million DM. Additional aid has been provided in the form of special equipment aid to a value of 600 million DM, two material aid programs totalling about 1,005 million DM and recently the deliver of Transtall aircraft worth 300 million DM result in the value of the material and services made available so far by the Federal Republic of Germany to Turkey free of charge amounting to 3,355 million DM.

The cooperation of German industry with military repair and production establishments as well as with government owned firms and private industrial enterprises in Turkey can be intensively expanded. In many talks with the managers of German industrial firms. It was found that they are ready and prepared to cooperate with the Turkish industry. German firms have realized that their future doesn't lie in mere exports of finished products. They are willing to share risks and successes with the Turkish partners for the benefit of both sides. And they know from experiences that Turks, devoted and industrious as they are at all levels from worker to engineer, are most reliable and therefore most valuable partners. [Ref. 6: p. 65]

The measures taken by the Turkish Government to promote the establishment of production facilities, to acquire the defense equipment and removal the bureaucratic obstacles to the establishment of joint ventures play a decisive role in this regard.

2. **Turkey-U.S Defense Cooperation**

U.S Congress enacted public law 75, providing assistance for Turkey in 1947. This first action under the Truman doctrine to "support free peoples who are resisting attempted subjugation by armed minorities or by outside pressures" was an historic departure from earlier American policies of peacetime isolationism. And it marked the beginning of a very special relationship between U.S and Turkey.

That relationship was broadened and deepened in 1952 when the protocol to the North Atlantic Treaty welcoming Greece and Turkey into NATO was approved. By the terms of the basic Treaty, this action meant recognition that these two European states were "in a position to further the principles of Treaty and to contribute to the security of the North Atlantic area", which despite its name , henceforth included the Eastern Mediterranean area as well.

Regarding U.S. aid to Turkey, the Congressional security assistance programmes note that, Turkey is a key NATO ally with important responsibilities for the defence of the vital southern flank of the Alliance. Turkey plays a stabilizing role in the Middle East, Southeast Asia region, and unfortunately Turkey has the lowest national income per capita in NATO, but she maintains the second largest armed forces in the Alliance. Because of the economic problems, Turkish Armed Forces need external aid in order to accomplish its defense objectives.

The U.S. has extended more than 6 billion dollars in grants and credits to Turkey for both economic and military purposes.

The Foreign Military Sales Financing Programme (FMS) offers credits to facilitate the purchase of the U.S. military equipment, spare parts,training and other services to meet basic defense requirements. Turkey finds it difficult to pay in cash for major defense acquisitions but is financially capable of assuming loan obligations for military purchases. In addition to standard treasury interest rates, a concessional rate component provides flexibility to address the needs of friendly nations with economic problems requiring more favourable credit terms but not an all grant programme.

The Military Assistance Programme (MAP) grant financing is made available to select countries for the acquisition of defence equipment and services. The United States provides MAP funds to coalition defence partners and front line states who are financially unable to maintain adequate self defence without diverting scarce resources from national economic development.

The Economic Support Fund (ESF) assists foreign nations in attacking the root causes of economic and political disruption and in creating the conditions necessary for sustainable economic growth. The programme promotes infrastructure development and helps receipents correct structural economic weakness.

The International Military Education and Training Programme (IMET) provides grant professional military training to foreign military and related civilian defense personnel in the United States and in facilities overseas. IMET participants receive instruction in U.S. military skills and doctrine, thereby improving their ability to manage their own country's military resources.

TABLE 1

U.S. DEFENSE AID TO TURKEY,
1984 TO 1987 ($ MILLION)

YEAR	1984		1985		1986		1987	
Forms of Assist.	Prop.	Admin. Appr.	Prop.	Admin. Appr.	Prop.	Admin. Appr.	Prop.	Admin. Appr.
Military Assist.								
FMS								
Concessional	-	-	275	250	345	330.1	455	
Market Rate	525	585	250	235	210	79.3	145	
Total FMS	525	585	525	485	555	409.4	600	
MAP	230	130	230	215	230	205.7	220	
IMET	4	3.1	4	3.1	4	3.3	4	
Tot.Mil.Assist.	759	718.1	759	703.1	789	618.4	824	
Economic Assist.								
Concessional	100	63.5	85	85	70	19.6		
Grant	75	75	90	90	80	100		
Tot.Econ. Asst.	175	138.5	175	175	150	119.6	150	
Tot. Sec. Assist.	934	856.6	934	878.1	939	738	974	

[Ref. 7: p. 36]

The amount of defense aid to Turkey by the United States needs approval of the Senate. Each year U.S. Senate members discuss the amount of economical and defense aid for Turkey. This discussion includes;

- U.S Bases in Turkey
- Minority Problems in Turkey
- The defense responsibility of Turkey in NATO
- Cyprus problem
- Turkey - Greece relationships
- The international relations of Turkey with Soviet Union and Arabic countries

- Political situation in Turkey
- Turkey's debt and economic problems

[Ref. 8: p. 11-18]

It can easily be understood that this kind discussion in U.S Senate may be influenced by minority people who live in the United States. This is a problem that damages Turk-U.S cooperation.

Another problem related to defense cooperation is the interest payment of the loan by the Turkish Government. The rate is usually equal to the market interest rate and it is cut by the United States Government automatically. When the total amount of the expense is increasing the net amount which can be used for system acquisition is continuously decreasing.

C. THE POTENTIAL INDUSTRIAL SUPPORT CAPABILITIES OF TURKEY

It has been pointed out that complete self-sufficiency in arms production could be achieved over a long period under peace-time conditions. Even the production of small arms and ammunition requires inputs of special metals and tools, and machine shop skills. When the list is extended to ships and aircrafts then the level of skills and equipment required are considerably more advanced and power sources, metal fabrication and instrumentation become more critical.

If the production or maintenance of arms is to generate constructive linkages in the domestic economy, the the manufacturing base must be capable of supplying the necessary inputs. Otherwise the components, tools and raw materials will be imported and the defense facilities will merely assemble the products.

During the 1960s, and particularly after the arms embargo, purchases of weapons began to make a bigger drain on Turkey's foreign exchange because of the wrong source selection.

1. Industrial Manufacturing Base

In general, there are figures available on the pattern of industrial employment in defense production which point to the following industries as begin the most important:

- Explosives and fire arms
- Iron and steel
- Light metals
- Steel tubes
- Metal working machine tools
- Engineers, small tools and gauges

- Industrial engines
- Other machinery
- Ordinance and small arms
- Other mechanical engineering
- Scientific, surgical and photographic instruments
- Electrical machinery
- Insulated wires and cables
- Telegraph, telephone apparatus
- Other electrical goods
- Ship building and ship repairing
- Metal industries
- Rubber

[Ref. 9: p. 815]

In explosives and fire arms production, there is only one firm, which is owned by the government, MKAE. It produces all kind ammunition for Army, Navy and Air Force, 20 mm ,35 mm anti aircraft gun for the navy under the licence of Oerlikon. In addition to these, MKAE has an agreement for the joint production of Maverick and Stinger Post with the European partners.

In iron and steel production, Turkish industry doesn't have any problem. All kinds of iron products and high quality steel are produced by the national industry.

Light metals, steel tubes, metal working machine tools, hydrolic presses,special mechanical equipments, high pressure hydrolic gear pumps (licenced from Dowty and Plassey), hydrolic steering units (under the licence of ZF- West Germany), various servo valves and power packages are produced by a couple of private firms.

Electromechanical products, electric motors, electronic components, electronic switch boards, copper wire and aluminium products are produced with European characteristics by Turkish industry.

As industrial engines, turbo charged diesel engines up to 280 Hp under the licence of MAN-West Germany, up to 2,000 Hp under the licence of Rolls Royce-UK, up to 5,000 Hp naval diesel engines under the licence of Sulzer-Switzerland are manufactured in Turkey. However in this group, all kinds steam turbines, internal combustion engines larger than 5,000 Hp and all kind gas turbines are not manufactured by the Turkish industry

Recently some of the private firms invested large amount capital in the electronic industry. But the largest electronic equipment producers are government owned firms. Today electronic industry produce VHF equipment (under the licence of Philips-Netherland), joint production in the European Maverick,low level air defense having an arrangement with Contraves (Sky Guard) and Raytheon (Sparrow), telecommunication equipments, analogue radio link systems, telephone sets, electronic teleprinter machines, resistors (under the licence of Bultronics Corporation-Japan), ceramic disks (under the licence of Thompson CSF-France) and the metallysed polyester film capacitors (under the licence of Acrotronics-Italy). [Ref. 10: p. 40]

Turkish industry has close relationships with European countries, especially West Germany,Switzerland, Italy and France and their industries. Some of the Turkish firms are engaged in joint production programmes with European partners. It is obvious that Turkish industry has a great potential to support European origin defense systems than the defense systems manufactured by non European friendly nations.

2. **Golcuk Naval Shipyard**

The first steps in the construction of the Golcuk Naval Shipyard were taken view of docking the battleship TCG YAVUZ, the former German HMS "GOEBEN". An important improvement programme was started after approval of the U.S aid programme in 1947. Additional facilities were constructed using national funds and most of the equipment which is in operation today was supplied through these programmes. 1962 was the turning point for the Golcuk Naval Shipyard, when complete submarine overhaul was started in cooperation with the bureau of ships and some U.S specialists.

During the 1970s Golcuk shipyard built two escort destroyers, BERK (commissioned date 1973), PEYK (commission date 1975). At the end of the 1980 new submarine construction facilities was constructed with the help of West Germany and first two submarine Type 209/1200 were commissioned by the Turkish Navy. The manufacturing , repair and maintenance staff of shipyard gained their experience on the wide variety of naval electrical and electronic equipment on board Turkish naval ships over the past 50 years. Shipyards now produce naval shipboard, electronic equipment such as fire control systems and it's derivatives, a communication security system and an under water telephone system.

Today the shipyard has 28,000 tons of total lifting capacity in floating docks, two slipways with dimensions of 150 x 24 and 80 x 20 meters, a building capacity for

ships up to 30,000 DW, one submarine construction facility which builds Type 209/1200 and employes 100 qualified engineers and about 5000 workers.

Maintenance facilities of the Golcuk Shipyard are responsible for supporting the Destroyers (U.S Gearing, U.S Carpenter, U.S Allen M. Sumner, U.S Robert H. Smith and U.S Fletcher classes) and Frigates (Ex German Koln, Turkish Berk classes). These vessels are completely overhauled by the shipyard periodically. The present overhaul and repair capacity of the shipyard includes:

- All kind hull repair for the different type vessels (from submarine to fiber sailing boat).
- All kind welding and related repair jobs.
- Overhaul of ship main propulsion system (steam propulsion system up to 30,000 hp for single system, diesel propulsion system up to 5,000 hp for single system)
- Production and maintenance of high capacity naval pumps and valves.
- Production and repair of all kinds electric motor (440 V, 3 Phase, 60 cycle and 380 V, 3 Phase, 50 Cycle) up to 1,000 hp AC and DC.
- Overhaul of electronic equipment, naval radars, sonar systems (AN-SPS/10, AN-SPA/29, AN-SPA/40, DECCA, Philips, AN-SQS 30)
- Overhaul of weapon systems (all kind gunnery, Mk 32, Mk 56 torpedos, ASROC, Harpoon Systems)

3. **Taskizak Naval Shipyard**

The Taskizak Naval Shipyard located on the Golden Horn within the present city limits of Istanbul was founded in 1455. In the following decades the yard built and maintained most of the vessels in the Ottoman Navy. The peace treaty after World War I, made Istanbul a demilitarized zone. Shipyard started working on merchant vessels and most of the machinery and equipment was transported to Golcuk and other shipyards.

In 1941, Taskizak Naval Shipyard was reopened on a very limited bases employing only skillful workers and a few engineers. Then started a period of growth to bring the yard gradually to the present size, employing 3,000 workers.

Today the functions of the shipyard are:

- New construction: designing, building and out fitting of military and merchant vessels up to 10,000 DWT.
- Repair work: which includes the periodic maintenance, overhaul and repair of about 190 ships per annual schedule plus emergency repairs when needed.
- Docking activities: this means dry docking of the above mentioned ships. Shipyard has two floating docks with lifting capacities of 3,000 and 2,500 tons respectively and a dry dock for small vessels of about 500 tons.

- Miscellenous activities: this covers all kinds of technical and practical assistance to military and industrial establishments in the area.

Taskizak, first of all is a naval shipyard with the primary purpose of constructing fast, modern naval vessels of relatively small tonnage and various types of modern landing vessels.

Since 1941 Taskizak has completed about 120 ships, large and small. The range of ships include landing ships,patrol craft, coast guard vessels, fast patrol boats, tankers and coasters. Some of the most important projects included construction of five DOGAN class guided missile boats armed with Harpoon under the licence of Lurssen, 14 high speed coast guard boats type SAR-33 which can be equipped with guided missile system. [Ref. 10: p. 46]

D. PERSONNEL TRAINING

The individual training is done in two phases as naval school training and professional training. Naval school training can be categorized in two groups, a school for officers and a school for petty officers.

The school for officers offers four years of high school with classes in foreign language (English) and modern science and mathematics programmes,
followed by four years in the Naval Academy where the students acquire the Bachelor's degree. The academy educates students in seven branches and teaches tactical, technical and logistic usage of arms , standing watch in surface units, and also trains officers to perform staff missions.

After graduation from the Naval Academy as a naval officer, each officer attends a two-month experimental course which is related with their duties in the navy. In Turkish navy, most of the ship systems are U.S originated and officers have enough theoretical background. At the end of the two month period, they have an acceptable level of experience with warships and weapon systems.

At the end of six year service in the navy, officers attend a six-month course which includes advanced level theoretical and practical training on special systems. They are appointed as senior officers after graduation from these courses.

Each year Turkish Navy selects 10-15 officers and sends them to other countries for higher education. The education expenses of the students who attend Naval Postgraduated School are paid from the FMS credits, the expenses of short term system courses in the United States are paid from the IMET. If Turkish Navy sends officers to another country like England and West Germany, the education expenses

will be paid by the Turkish Government. Each year total number of the Turkish officers who study at the United States schools average 45. This number is really high, if we compare it with the total number of officers in the Turkish Navy (2700 officers). In personnel training, Turkish Navy has close cooperation with the United States.

The preparation school for petty officers runs three years, providing the petty officer candidates with general knowledge and professional training to high school level. The advanced school for petty officers is a school which provides the students with theoretical and practical training consolidating their professional knowledge and getting them accustomed to life on board.

The training of the petty officers in the Turkish Navy continues in order to improve their operational capability by means of practical training at training bases. The problem is during their education at the preparation school and advanced school they don't have enough theoretical background about U.S originated systems and foreign language (English). Their skills are relatively lower.

Of 18 month Military service is required in Turkey. All do enlisted service when they reach 20 years of age. All enlisted personnel go on the ship without taking any previous courses about the ship and ship systems. Their educational background isn't enough to learn U.S. originated ships and ship systems. They can learn European originated systems more easily by using their civil life experience. Common problems are the same as petty officers have.

But training facilities were established with the help of the United States and training personnel have strong backgrounds with U.S designed ship and weapon systems. If the Turkish Navy decides to acquire a defense system different from a U.S designed system, these training facilities should be reestablished and training personnel must be sent to system manufacturer's facilities in order to improve their experience on the new system. The establishment of new facilities and additional training in other countries will increase the total life cycle cost of the defense systems.

IV. COST-BENEFIT ANALYSIS

The first step for the procurement of the new defense systems is to decide whether the Turkish Navy needs new frigates/destroyers or not.

In chapter two we gave some background about the capabilities of the Russian and Syrian naval forces in Black sea, Aegean sea and Mediterranean sea, and the physical characteristics of these operational areas. And we outlined the present capabilities of the Turkish Destroyer Fleet.

It is obvious that, the present Turkish Destroyer fleet doesn't have any surface to air (SAM), effective short range air/missile defense gun systems. The present surface to surface missile systems are limited. The economic life of the present destroyer fleet is exceeded, and maintenance and logistic support is insufficient and expensive.

In the operational area the destroyer fleet doesn't have enough capabilities to win in actions with probable enemy warships. As a decision maker we concluded that the present structure of the Turkish Destroyer Fleet must be changed as soon as possible.

Changing all destroyers will be too expensive for the Turkey. But in the short run, it has enough resources to acquire three or four new frigates and modernize some number of present destroyers with more effective weapons.

A. OBJECTIVES

In the decision making process the objectives are what military aim or aims are we trying to accomplish with the forces, equipments, projects or tactics that the analysis is designed to compare. Often the statement the objectives is the hardest part of analysis to aid the decision maker, just like they are in our case.

The easiest way of defining objectives is to outline the tasks of Turkish Navy. Within the frame work of threat evaluation and the responsibilities in pursueing the East-West balance Navy objectives can be outlined as follows:

- to organize, plan and conduct surveillance (early warning) systems within the naval theatre of operations.
- to test by exercises the operations that will destroy or neutralize the hostile enemy forces. In case of engagement:
- to establish naval control in order to neutralize the enemy's naval operations.
- to organize and conduct the control and protection for merchant shipping.
- to conduct defensive and offensive mine operations.

- to conduct amphibious operations when necessary.
- to provide naval support for land operations.
- to defend bases and ports.

The Turkish Destroyer Fleet by itself is responsible to accomplish all these tasks except defensive or offensive mine operations and amphibious operations. So our objectives will be to meet the requirements which are necessary in order to accomplish given tasks. [Ref. 10: p. 38]

B. ALTERNATIVES

The alternatives are the options or means available to the decision maker by which the objectives can be attained. Alternatives need not to be obvious substitutes for each other nor perform the same specific functions. In our case the best alternative would be to join the NATO frigate replacement programme (NFR 90) if it isn't only in theory.

Based on the present structure of the Turkish Navy the other best frigate/destroyer sources are the United States and West Germany. The United States has a program to construct some number Arleight Burke class destroyers which will be in operation during the 1990s. These destroyers are too large in order to accomplish given mission in narrow waterways like Aegean sea and Turkish straits and too expensive (S 780,000,000) for a country which has limited resources for defense expenses. Instead of these destroyers, we select Perry class frigates which had been deployed since 1960s by the United States and a couple friendly NATO nations. The shipsystems of these frigates are recently upgraded and maintainability ,reliability, supportability characteristics are at high level because of the long production run.

West Germany has Type 122 frigate program for its own navy. We select the Meko 200 frigates which conversion of the Type 122 frigates with same weapon systems and smaller hull.

The Turkish navy has these candidates to restructure its destroyer fleet based on two different force structures. These force structures are as in Table 2. and Table 3[1].

The specifications and backgrounds about these destroyers and frigates are as follows:

[1]LCC of each force structure are shown in Table 9.

TABLE 2

FORCE STRUCTURE ONE

1st Squadron	2nd Squadron	3rd Squadron
1 Perry Classs	1 Perry Class	1 Perry Class
Frigate	Frigate	Frigate
3 modified Gearing class destroyers	3 modified Gearing class destroyers	3 modified Gearing class destroyers
1 unmod. destroyer	1 unmod. destroyer	1 unmod. destroyer

Total 15 year LCC= $ 2.61 Billion

TABLE 3

FORCE STRUCTURE TWO

1st Squadron	2nd Squadron	3rd Squadron
2 Meko 200 Frigate	1 Meko 200 Frigate	1 Meko 200 Frigate
2 modified Gearing class destroyers	2 modified Gearing class destroyers	2 modified Gearing class destroyers
1 unmod. destroyer	1 unmod. destroyer	1 unmod destroyer

Total 15 year LCC= $ 2.36 Billion

1. **Perry Class Frigates**

They are follow-on ships to the large number of frigates built in 1960s and early 1970s, with the later ships emphasising anti-ship/aircraft/missile capabilities while the previous classes were oriented primarily against submarines. Total number of the frigates which have been constructed up to now is 61. This long construction run reduced the unit-ship cost while increasing the maintainability, reliability and supportability.

This frigate is one of the strongest candidate for Turkish Destroyer Fleet, because of the reasons we mentioned before. In addition to them, Turkey can purchase these frigates by using FMS credits. As we mentioned before Turkey doesn't have enough resources to buy these frigates by paying their costs in short period of time, but it has capability in order to pay their costs in long-run. FMS provides credit which interest rate is lower than market interest rate, and this reduces the total life-cycle cost of the Turkish Destroyer Fleet.

Another important factor is, the training agreement between U.S. and Turkey which can provide periodical personnel training for these frigates at low cost. Present Logistic Support agreement includes some of the spare/support equipments which are required for these frigates will reduce additional logistic support cost.

Data are of prime importance, and efforts to develop a satisfactory data base must be started long before it becomes necessary to use such data for specific projects. Both equipment specifications and operational assumptions must be covered. [Ref. 11: p. 82]

FRIGATE SPECIFICATIONS

I. PRIMARY EQUIPMENT SPECIFICATIONS

A- Performance Specifications

a- Displacement : 2750-3583 ton

b- Speed : 29 knots

c- Operational range : 4500 miles at 20 knots

2. Electronics

a- Radar :

Long range Radar: AN/SPS 49 320 km max range

Search and navigation: AN/SPS 55 30 km max range

Weapon control: STIR 180 km max range

b- ECM/ECCM : SLQ 32 EW system

Mk 36 Super RBOC Chaffrack

c- Sonar :AN/SQS 56 30,000 yds. max range

T-Mk 6 Fanfare torpedo decoy system

d- Fire control system : Mk 92 weapon control system

Mk 13 weapon direction system

3. Weapons

a- Guns

76 mm OTO MELERA	20 mm PHALANX Mk 16 CIWS
90 rounds/min.	3000 rounds / min.
18,000 yds max range	4,000yds max range

b- A/S Weapons : 2 triple torpedo tubes Mk 32

8,600 yds max range at 15 knots ship speed

c- Missiles

SSM Harpoon	SAM Standard
90 km max range	16 km. max range
4 rounds	36 rounds

4. Engines

a- Power: 40,000 shp single shaft

b- Type: Gas turbine

c- Specific fuel consumption: F 76

d- Fuel consumption: 2.3 ton/hr at 20 knots

B- Other Physical Data

.a- Size data: (135.6 x 13.7 x 7.5 ; 4.5 at sonar)

b- Basic metal types

Above the main deck construction metal is aluminium

Below the main deck construction metal is steel

C- Manufacturers : Bath Iron Works - USA

Todd Shipyards - USA

II. Support equipment specifications: New facilities for the overhaul of gas turbine propulsion system is required which has $ 50,000,000 cost.

2. **Meko 200 Class Frigate**

MEKO 200 class frigates are the conversion type of F122 Frigate which are deployed by the West German Navy. The propulsion plant will be adopted for the Turkish MEKO 200 class frigate is an diesel drive with 20 cylinder engines of the MTU 1163 series with a total maximum power 25,000 Kw acting on two variable pitch propellers via rank reduction gears instead of gas turbine drive system in original design.

Equipments for these frigates can be supplied from the United States by using FMS credits. These equipments are 5" guns Mk 45 Mod. 1, AN/SQS-56 sonars, Sea

sparrow SAM systems, HARPOON SSM systems, and torpedo tubes Mk 32 Mod. 5. It is the first time that U.S equipment acquired with FMS loans is integrated into a non U.S designed weapon system. The first two ships will be constructed by the West German shipyards, and the next two ships will be constructed in Turkish naval shipyards.

SYSTEM SPECIFICATIONS

I. PRIMARY EQUIPMENT SPECIFICATIONS

A. Performance Specifications

1- Ship frames

a- Displacement: 2000 ton standard, 2784 ton full

b- Speed: 27 knots

c- Operational range: 4000 miles at 20 knots

2.- Electronics

a- Radar

Long range air search: DA 8 APS 49; 180 km max range

Surface search radar: Plessey Dolphin; 30 km max range

Weapon control: STIR; 180 km max range

b- ECM/ECCM: Hycor/Super RBOC launcher

Nixie towed jammer

c- Sonar: SQS-56 hull mounted; 30,000 yds max range

d- Fire control system: Signaal WM 25

STIR and Seawco

Tacan

3. Weapons

a- Guns:

One 5" U.S Mk 45	Three Sea guard CIWS
20 round/minute	3400 rounds/minute
20,000 yds. max range	3200 yds max range

b- A/S Weapons:

2 triple Mk 32 ASW torpedo tubes

Max range 8,600 yds. at 15 knot ship speed

c- Missiles:

SSM; Harpoon	SAM; Standard
90 km max range	16 km max range
8 rounds	20 rounds

4. Engines:

a- Power: 40,000 shp

b- Type: Diesel engine

c- Specific fuel consumption: F 76

d- Fuel Consumption: 2 ton/hour at 20 knot speed

B. Other Physical Data:

a- Size data: (110.5 x 13.3 x 4 ; 4.2 meters at sonar)

b- Basic material types:

Above the main deck construction material is aluminium

Below the main deck construction material is steel

C. Manufacturers: Blohm and Voss, Howaldtswerke-West Germany

Golcuk Naval Shipyard-Turkey

II. SUPPORT EQUIPMENT SPECIFICATIONS

The present maintenance facilities are continuously modernized with the technical and financial assistance of the West Germany. All the expenses for the maintenance equipment are paid by the West Germany which free to charge.

III. OPERATIONAL CONCEPT SPECIFICATIONS

a- Force size: Each MEKO 200 frigate will operate with two or three modernized Carpenter/Gearing class destroyers and one unmodernized Gearing class destroyer.

b- Geographical deployment: This frigate was designed to operate in narrow seawater. So it is superior in the Aegean sea and Turkish straits

c- Activity rates: Each frigate operates 2000 hours each year.

d- Organizational Concept: Each squadron consist of with five frigates/destroyers and three squadrons are under the command of Turkish Destroyer Fleet.

e- Alert capability: At least one squadron should be able to depart from the main base in 30 minutes.

f- Degree of system automation: High

g- Duration of system in operation: Ten days each month

h- Training concept: Each two years one active SSM firing, one SAM firing and each year twenty times active gun firing training. subsect Modernized Carpenter Class Destroyer

The Carpenter class destroyers require significant upgrade of weapons to be as capable as other escorts currently operating in the advanced navies. Turkish Navy Officals stated that the Carpenter class destroyers should be compared with the Perry class escorts. Upgrading these destroyers to the Perry class escort's level would make them comparable to the most modern escort ships in the navy. But the initial estimation showed that it would cost $ 198 million to overhaul and upgrade these destroyers to be combat capable. This includes $ 65 million for an overhaul to extend the life of the ships an additional ten years. [Ref. 12: p. 3]

So large expenses for ten year operational life for these destroyers isn't economic. Instead of the large modernization program, Navy Officals advised that these destroyers can be upgraded to have the capability to meet the requirements of minimum level operation. The cost statement of this modernization is shown in Table 4.

TABLE 4

COST ESTIMATION
IN MILLION DOLLARS

JOB DEFINITION	MATERIAL	INSTALLATION	TOTAL
Overhaul	-	-	20.000
Convert sonar from SQS-23 to SQQ-23	8.372	2.939	11.311
Install Harpoon	2.847	1.094	3.441
Upgrade habitability	-	-	1.100
Upgrade communication	1.576	2.040	3.616
Feasibility and design	-	-	1.187
TOTAL	-	-	40.655

C. MODEL

The emphasis on comparing two systems for the same missions is called system comparison studies. It is presumed that each competing system has already been "sub-optimized" as to its configuration. The cost of each alternative are summarized by a single life cycle cost estimate (LCC). The description of the effectiveness of each alternative is provided separately.

Typically, system comparison studies have the following characteristics relating to system life-cycle cost;

- Costs are generally required in less detail than in system configuration studies where the emphasis was on components.
- In this type of study the specific spread of costs over time is usually ignored or treated as a secondary problem.

[Ref. 11: p.50]

D. ESTIMATING LIFE CYCLE COST

This step in the process is concerned with the actual calculation of the dollar estimate. Cost estimates are developed within the framework of cost-element lists. Cost elements are subdivisions of the cost categories; R&D, production and construction cost, operation and maintenance cost and system retirement and phase-out cost. LCC cost involves all costs associated with the system life cycle, to include;

- Research and Development Cost (R&D)- the cost of feasibility studies, system analysis, detail design and development, construction, assembly and test of engineering models, initial system test and evaluation and associated documentation.
- Production and Construction Cost- the cost of construction, assembly and test of operational systems, operation and maintenance of the production capability, and associated initial logistic support requirements (e.g., test and support equipment development, training, entry of items into the inventory, technical data development, facility construction etc.).
- Operation and Maintenance Cost- the cost of sustaining operation, personnel and maintenance support, spare/repair parts and related inventories, test and support equipment maintenance transportation and handling, facilities, modifications and technical data changes and so on.
- System Retirement and Phase-out Cost- the cost of phasing the system out of the inventory due to obsolescence or wear out.

In Turkish Navy case we will buy some number of frigates which are constructed, tested and deployed by the United States or West Germany. So we will not focus on R&D and production and construction cost because they are included in the initial procurement cost. Our life cycle cost formula is as in equation 4.1.

$$LCC = [C_{pc} + C_o + C_{op}] \quad \text{(eqn 4.1)}$$

LCC = Life Cycle Cost

C_{pc} = Procurement Cost

C_o = Operation Cost

C_{op} = System Phase-out Cost

1. Procurement Cost

Procurement cost includes Research and Development (R&D) costs, production and construction costs. Major cost components are system construction cost, initial logistic support cost, maintenance facilities construction cost and initial operating and maintenance training costs.

2. Operation and Maintenance Cost

Includes all costs associated with the operation and maintenance support of the system throughout its life-cycle. Specific categories cover the cost of the system operation, maintenance, sustaining logistic support, equipment modifications and system/equipment phase-out and disposal. Costs are generally determined for each year throughout its life-cycle as in Equation 4.2.

$$C_o = [C_{oo} + C_{om} + C_{on} + C_{op}] \quad \text{(eqn 4.2)}$$

C_{oo} = Cost of system life-cycle operations

C_{om} = Cost of system life-cycle maintenance

C_{on} = Cost of system modifications

C_{op} = Cost of system phase-out

a. Operations Cost (C_{OO})

Includes all costs associated with the actual operation (not maintenance) of the system throughout its life-cycle. Specific categories cover the costs of system operational personnel (system operator), the formal training of the operators, operational facilities, support and handling equipment necessary for system operation. Our operation cost calculation formula will be as in Equation 4.3.

$$C_{oo} = [C_{oop} + C_{oot} + C_{oof} + C_{ooe}] \quad \text{(eqn 4.3)}$$

C_{oop} = Operating personnel cost

C_{oot} = Cost of operator training

C_{oof} = Cost of operational facilities

C_{ooe} = Cost of support and handling equipment

(1) *Operating Personnel Cost* (C_{OOP}). This category covers the costs of operating personnel as allocated to the system. A single operator may operate more than one system, but costs should be allocated on an individual system basis. Such cost include base pay or salary and allowances; fringe benefits (insurance, medical retirement), travel, clothing allowances, etc. Both direct and overhead costs are included. The operating personnel calculation formula is as in Equation 4.4.

$$C_{oop} = (T_o)(C_{po})(Q_{po})(N_{po})\ (\%\ \text{Allocation}) \qquad \text{(eqn 4.4)}$$

T_o = Hours of system operation

C_{po} = Cost of operator labor

Q_{po} = Quantity of operator labor

N_{po} = Number of operating systems

(2) *Operator Training Cost* (C_{OOT}). Initial operator training cost is included in the procurement cost. This category covers the formal training of personnel assigned to operate the system. Such training is accomplished on a periodic basis throughout the system life-cycle to cover personnel replacements due to attrition. Total costs include instructor time, supervision, student pay and allowances while in school, training facilities (allocation of portion of facility) required specifically for formal training, training aids, equipment and data, and student transportation as applicable. Operator training cost calculation formula is as in Equation 4.5.

$$C_{oot} = (Q_{so})(T_t)(C_{top}) \qquad \text{(eqn 4.5)}$$

C_{so} = Quantity of student operators

T_t = Duration of training program (week)

C_{top} = Cost of operator training (S/student-week)

(3) *Operational Cost* (C_{OOF}). Initial acquisition of the frigates is included in procurement cost. This category covers the annual recurring costs associated with the fuel, ammunition, missiles for test fire during the operation, etc. Utility costs are

also included, and are proportionately allocated to each frigate. Cost calculation formula is as in Equation 4.6.

$$C_{oof} = (C_{ppe} + C_u)(\%\text{Allocation X } N_{os}) \quad \text{(eqn 4.6)}$$

C_{ppe} = Cost of operational facility support ($/unit)
C_u = Cost of utilities
N_{os} = Number of operational units

(4) *Support and Handling Equipment Cost (C_{ooe}).* Initial acquisition cost for operational support and handling equipment is covered in initial procurement cost. This category includes the annual recurring usage and maintenance costs for these items which are required to support system operation throughout system life-cycle. The costs specifically cover equipment operation (not covered elsewhere), equipment corrective maintenance and preventive maintenance. The cost calculation formula is as in Equation 4.7.

$$C_{ooe} = [C_{ooo} + C_{oou} + C_{oos}] \quad \text{(eqn 4.7)}$$

C_{ooo} = Cost of operation
C_{ooo} = Cost of equipment corrective maintenance
C_{oos} = Cost of equipment preventive maintenance

$$C_{ooe} = [(Q_{ca})(M_{mhc})(C_{ocp}) + (Q_{ca})(C_{mhc}) + (Q_{ca})(C_{oc})]N_{os} \quad \text{(eqn 4.8)}$$

Q_{ca} = Quantity of corrective maintenance actions
M_{mhc} = Corrective maintenance man-hours
C_{ocp} = Corrective maintenance labor cost
C_{mhc} = Cost of material handling
C_{dc} = Cost of corrective maintenance documentation
N_{os} = Number of systems

$$C_{oos} = [(Q_{pa})(M_{mhp})(C_{oop}) + (Q_{pa})(C_{mhp}) + (Q_{pa})(C_{dp})]N_{os} \quad \text{(eqn 4.9)}$$

Q_{PA} = Quantity of preventive maintenance action

M_{mhp} = Preventive maintenance manhour
C_{opp} = Preventive maintenance labor cost
C_{mhp} = Cost of material handling
C_{dp} = Cost of preventive maintenance documentation
N_{os} = Number of operational systems

b. Maintenance Cost (C_{om})

Includes all sustaining maintenance labor, spare/repair parts, test and support equipment, transportation and handling, replenishment training, support data and facilities necessary to meet the maintenance needs of the prime equipment throughout its life-cycle. Such needs include both corrective and preventive maintenance requirements at all units.

The Maintenance Cost calculation formula as in Equation 4.10.

$$C_{om} = [C_{omm} + C_{omx} + C_{oms} + C_{omt} + C_{omp} + C_{omf} + C_{omd}] \qquad \text{(eqn 4.10)}$$

C_{omm} = Maintenance personnel and support cost
C_{omx} = Cost of spare/repair parts
C_{oms} = Test and support equipment maintenance cost
C_{omt} = Transportation and handling cost
C_{omf} = Cost of maintenance facilities
C_{omd} = Cost of technical data

(1) *Maintenance Personnel and Support Cost (C_{omm}).* Includes corrective and preventive maintenance labor associated material handling and supporting documentation. When a system malfunction occurs or when a scheduled maintenance action is performed, personnel manhours are expanded the handling of spares and related materials takes place, and maintenance action reports are completed. This category includes all directly related costs, and calculation formula is as in Equation 4.11.

$$C_{omm} = [C_{oou} + C_{oos}] \qquad \text{(eqn 4.11)}$$

C_{oou} = Cost of equipment corrective maintenance
C_{oos} = Cost of equipment preventive maintenance

(2) *Corrective Maintenance Cost* (C_{oou}). This category includes the personnel activity costs associated with the accomplishment of corrective maintenance. Related spares, test and support equipment, transportation,training and facility costs are covered in initial acquisition cost. Total cost includes the sum of individual costs for each maintenance actions anticipated over the entire system life-cycle. A maintenance action includes any requirement for corrective maintenance resulting from catastrophic failures, dependent failures, operator/maintenance induced faults, manufacturing defects, etc. The cost per maintenance action considers the personnel labor expended for direct tasks (localization, fault isolation,remove and replace, repair, verification), associated administrative, material handling and maintenance documentation (failure reports, spares issue reports). Both direct labor and overhead costs are included. The cost calculation formula is as seen in Equation 4.12.

$$C_{oou} = [(Q_{ca})(M_{mhc})(C_{ocp}) + (Q_{ca})(C_{mhc}) + (Q_{ca})(C_{dc})](N_{ms}) \qquad \text{(eqn 4.12)}$$

Q_{ca} = Quantity of corrective maintenance actions
M_{mhc} = Corrective maintenance manhours
C_{ocp} = Corrective maintenance labor cost
C_{mhc} = Cost of material handling
C_{dc} = Cost of documentation
N_{ms} = Number of maintenance units

(3) *Preventive Maintenance Cost* (C_{oos}). This category includes the personnel activity costs associated with the accomplishment of preventive or scheduled maintenance. Total cost includes the sum of individual costs for each preventive maintenance action multiplied by the quantity of maintenance actions anticipated over the system life-cycle. A maintenance action includes serving, lubrication, inspection, overhaul, calibration, periodic system check-outs, and the accomplishment of scheduled critical item replacements. The costs per maintenance action consider the personnel labor expended for preventive maintenance tasks, associated administrative, material handling and maintenance documentation. Both direct labor and overhead costs are included. The cost calculation formula is as in Equation 4.13.

$$C_{oos} = [(Q_{pa})(M_{mhp})(C_{opp}) + (Q_{pa})(C_{mhp}) + (Q_{pa})(C_{dp})]N_{ms} \qquad \text{(eqn 4.13)}$$

Q_{pa} = Quantity of preventive maintenance actions
M_{mhp} = Preventive maintenance manhours per action
C_{opp} = Preventive maintenance labor costs
C_{mhp} = Cost of material handling per action
C_{dp} = Cost of documentation per action
N_{ms} = Number of maintenance units

(4) *Spare/Repair Parts Cost* (C_{omx}). This category includes all replenishment spare/repair parts and consumeable materials (e.g., oil, lubricants, fuel, etc.) that are required to support maintenance activities associated with prime equipment, operational support and handling equipment, test and support equipment, and training equipment at each unit. This category covers the cost of purchasing, the actual cost of material itself; and the cost of holding and maintaining items in the inventory. Costs are assigned to the applicable level of maintenance. Specific quantitative requirements for spares are derived from the logistic support analysis. Cost calculation formula is as in Equation 4.14.

$$C_{omx} = [C_{so} + C_{si} + C_{sd} + C_{ss} + C_{sc}] \qquad \text{(eqn 4.14)}$$

C_{so} = Cost of organizational spare/repair parts
C_{si} = Cost of intermediate spare/repair parts
C_{sd} = Cost of depot spare/repair parts
C_{ss} = Cost of supplier spare/repair parts
C_{sc} = Cost of consumeables

$$C_{so} = \sum[(C_a)(Q_a) + \sum(C_{mi})(Q_{mi}) + \sum(C_{hi})(Q_{hi})] \qquad \text{(eqn 4.15)}$$

C_a = Average cost material purchase order
Q_a = Quantity of purchase orders
C_m = Cost of spare item
Q_m = Quantity of items required or demanded
C_h = Cost of maintaining spare item in the inventory
Q_h = Quantity of the item in the inventory
C_{si} , C_{sd} and C_{ss} are determined in a similar manner.

(5) *Test and Support Equipment Cost* (C_{oms}). Initial acquisition cost for test and support equipment is covered in the system initial acquisition cost. This category includes the annual recurring life-cycle maintenance cost for test and support equipment at each unit. Maintenance constitutes both corrective and preventive maintenance, and the costs are derived on a similar basis with prime equipment. In some instances specific items of test and support equipment are utilized for more than one system, and in such cases, associated costs are allocated proportionately to each system concerned. The cost calculation formula is as in Equation 4.16.

$$C_{oms} = [C_{seo} + C_{sei} + C_{sed}] \qquad \text{(eqn 4.16)}$$

C_{seo} = Cost of organizational test and support equipment
C_{sei} = Cost of intermediate test and support equipment
C_{sed} = Cost of depot test and support equipment

$$C_{seo} = [C_{oou} + C_{oos}] \qquad \text{(eqn 4.17)}$$

C_{oou} = Cost of equipment corrective maintenance
C_{oos} = Cost of equipment preventive maintenance

$$C_{oou} = [(Q_{ca})(M_{mhc})(C_{ocp}) + (Q_{ca})(C_{mhc}) + (Q_{ca})(C_{dc})]N_{ms} \qquad \text{(eqn 4.18)}$$

Q_{ca} = Quantity of corrective maintenance actions
M_{mhc} = Corrective maintenance manhours
C_{ocp} = Corrective maintenance labor cost
C_{mhc} = Cost of material handling per corrective action
C_{dc} = Cost of documentation per corrective action
N_{ms} = Number of units

$$C_{oos} = [(Q_{pa})(M_{mhp})(C_{opp}) + (Q_{pa})(C_{mhp}) + (Q_{pa})(C_{dp})]N_{ms} \qquad \text{(eqn 4.19)}$$

Q_{pa} = Quantity of preventive maintenance actions
M_{mhp} = Preventive maintenance actions
C_{opp} = Preventive maintenance labor cost

C_{mhp} = Cost of material handling per preventive action

C_{dp} = Cost of documentation per preventive action

N_{ms} = Number of units

C_{sei} and C_{sed} are determined in similar manner.

(6) *Transportation and Handling Cost* (C_{omt}). This category includes all sustaining transportation and handling (or packaging and shipping) between organizational, intermediate, depot and supplier facilities in support and maintenance operations. This includes to return of faulty material items to supplier, shipment of spare/repair parts, personnel,data,etc., from the supplier to forward operational units. Cost calculation formula is as in Equation 4.20.

$$C_{omt} = [(C_t)(Q_t) + (C_p)(Q_p)] \qquad \text{(eqn 4.20)}$$

C_t = Cost of transportation

C_p = Cost of packaging

Q_t = Quantity of one = way shipping

$$C_t = (W)(C_{ts}) \qquad \text{(eqn 4.21)}$$

W = Weight of item

C_{ts} = Shipping cost

$$C_p = (W)(C_{tp}) \qquad \text{(eqn 4.22)}$$

C_{tp} = Packaging cost ($/ton)

(7) *Maintenance Training Cost* (C_{on}). This category covers the formal training of personnel assigned to maintain the prime equipment, test and support equipment and training equipment. Such training is accomplished on a periodic basis throughout the system life-cycle to cover the personnel replacements due to attrition. Total cost includes instructor, supervision, student pay and allowances while in school, training facilities (allocation of portion of facility required specifically for formal training) and student transportation. The cost calculation formula is as in Equation 4.23.

$$C_{omp} = [(Q_{sm})(T_t)(C_{tom})] \quad \text{(eqn 4.23)}$$

Q_{sm} = Quantity of maintenance students
C_{tom} = Cost of maintenance training
T_t = Duration of training program

(8) *Maintenance Facilities Cost* (C_{omf}). Initial acquisition cost for maintenance facilities is included in initial system acquisition cost. This category covers the annual recurring costs associated with the occupancy and support (repair, modification,paint,etc.,) of maintenance shops at all units throughout the system life-cycle. On some occasions, a given maintenance shop will support more than one system, and in such cases, associated costs are allocated proportionately to each system concerned. Cost calculation formula is as in Equation 4.24.

$$C_{omf} = (C_{ppm} + C_u)(\%\ \text{Allocation})(N_{ms}) \quad \text{(eqn 4.25)}$$

C_{ppm} = Cost of maintenance facility support per unit
C_u = Cost of utilities per unit
N_{ms} = Number of maintenance units

(9) *Technical Data Cost* (C_{omd}). Initial technical data preparation costs are included in initial system acquisition cost. This category includes any other data necessary to support the operation and maintenance of the system throughout its life-cycle. Our cost calculation formula is as in Equation 4.26.

$$C_{omd} = \sum C_{omdi} \quad \text{(eqn 4.26)}$$

C_{omdi} = Cost of specific data item

(10) *System Equipment Modification Cost* (C_{on}). Throughout the system life-cycle, after equipment has been delivered to the operational field, modifications are often proposed and initiated to improve system performance, effectiveness or a combination of both. This category includes modification kit design, material, installation and test instructions, personnel and supporting resources for incorporateing the modification kit, technical data change documentation, formal training to cover the new configuration, spares, etc. The modification may effect all elements of logistics. Cost calculation formula is as in equation 4.27.

$$C_{on} = \sum C_{oni} \quad \text{(eqn 4.27)}$$

C_{oni} = Cost of specific modification

3. **System Phase-out Cost (C_{op})**

This category covers the liability or assets incurred when an item is condemned or disposed. This factor is applicable throughout the system/equipment life-cycle when phase-out occurs. This category represents the only element of cost that may turn out to have a negative value-resulting when the reclamation value of the end item is larger than the disposal cost. The cost calculation formula is as in Equation 4.28.

$$C_{op} = [(F_c)(Q_{ca})(C_{dis} - C_{rec})] \quad \text{(eqn 4.28)}$$

F_c = Condemnation factor
Q_{ca} = Quantity of corrective maintenance actions
C_{dis} = Cost of system/equipment disposal
C_{rec} = Reclamation value

E. COST CALCULATION

We will calculate annual operating cost for each type frigate/destroyer in the given two different force structures. Acquisition price of the new frigates and purchasing price of the equipments/systems which are necessary for modernization of the present Carpenter/Gearing class destroyers are obtained from different selling agreements.

1. **Cost Calculation For MEKO 200 Frigates**

MEKO 200 class frigate has $ 290,000,000 initial acquisition cost for Turkish Navy which relatively cheaper than U.S Perry class frigates. This initial acquisition cost will be paid in seven years by the Turkey.

The first two frigates will be constructed by the West German shipyards and the last two frigates will be constructed by the Turkish Naval shipyards. The main ship systems, weapon systems will be prepared by the West German shipyards and system manufacturers. Then they send them to the Turkish shipyards. The hull and simple systems will be constructed in the Turkish shipyards, then ship systems and weapon systems will be mounted by shipyard personnel with the technical assistance of West Germany.

Defense systems which have high technology are labor intensive construction. In Turkey, labor cost is low if it is compared with the labor cost in West Germany. The differance in labor cost will be saving for Turkish Navy. In addition to this some simple equipment and spare parts can be manufactured by the Turkish industry at relatively low cost.

The cost of main weapon systems which can be purchased from the United States will be paid by using FMS credits. It means during the pay-back period, the equipment cost will not be higher than their cash price. Because the FMS interest rate is lower than market interest rate.

In annual cost calculation, operating personnel cost isn't high because of the low salaries of the operating personnel. Operational cost is relatively low, since the annual active operation is only 2000 hours and active missile firing for training and test is limited. When ship in the main base steam, water, electricity will be supplied by the shore facilities.

Spare part and inventory holding cost isn't as high as they are in Perry class frigate's cost calculation. Because spare part lead time and average inventory level are smaller and some of the spare parts will be manufactured by the Turkish industry.

Operating personnel training cost higher. Some of the systems in this ships are new for operating personnel and training takes long time. Small number of operator will be trained in West Germany and Netherland in order to learn system effectively.

Spare part cost is calculated by using data which obtained from previously deployed Berk class frigates. Maintenance personnel cost is calculated by using the maintenance labor allowances which derived by the shipyards. Maintenance facilities cost will be shared by each frigate/destroyer based on their maintenance work load.

Based on these assumptions annual cost calculation is shown shown in Table 5.

a. Cost Calculation For Perry Class Frigate

This frigate has $ 360,000,000 initial acquisition price. This price doesn't include maintenance facilities cost which are essential for the maintenance of gas turbine main propulsion system. Additional maintenance facilities cost will be approximately $ 50,000,000 and will be divided among the three frigates. These frigates can be purchased by using FMS credits and payment can be made in ten years. The net present value of the acquisition cost will not be higher than the cash price of these destroyers, because of the low interest rate of FMS credits.

TABLE 5

ANNUAL COST FOR MEKO 200

OPERATION MAINTENANCE COST	
OPERATION COST	
Operation personnel cost	309,200
Operator training cost	242,100
Operational cost	1,637,200
Support and handling cost	157,900
TOTAL	2,346,400
MAINTENANCE COST	
Maintenance personnel and support cost	50,900
Cost of spare repair parts	684,200
Test and support cost	19,600
Transportation and handling cost	4,200
Maintenance training cost	3,500
Maintenance facilities cost	438,600
Technical data cost	10,500
TOTAL	1,211,500
TOTAL OPERATION COST	3,557,900
THREE YEAR OVERHAUL COST	
Overhaul labor cost	285,000
Overhaul facilities cost	168,000
Overhaul material/spare part cost	789,375
TOTAL OVERHAUL COST	1,242,375

In the annual cost calculation of the Perry class frigates operation personnel cost isn't high since the low operator allowances. Operator training cost is lower than it is in MEKO 200 class frigate annual cost calculation. Almost every operator is familiar with the United States designed systems, and training can be accomplished in the present training facilities.

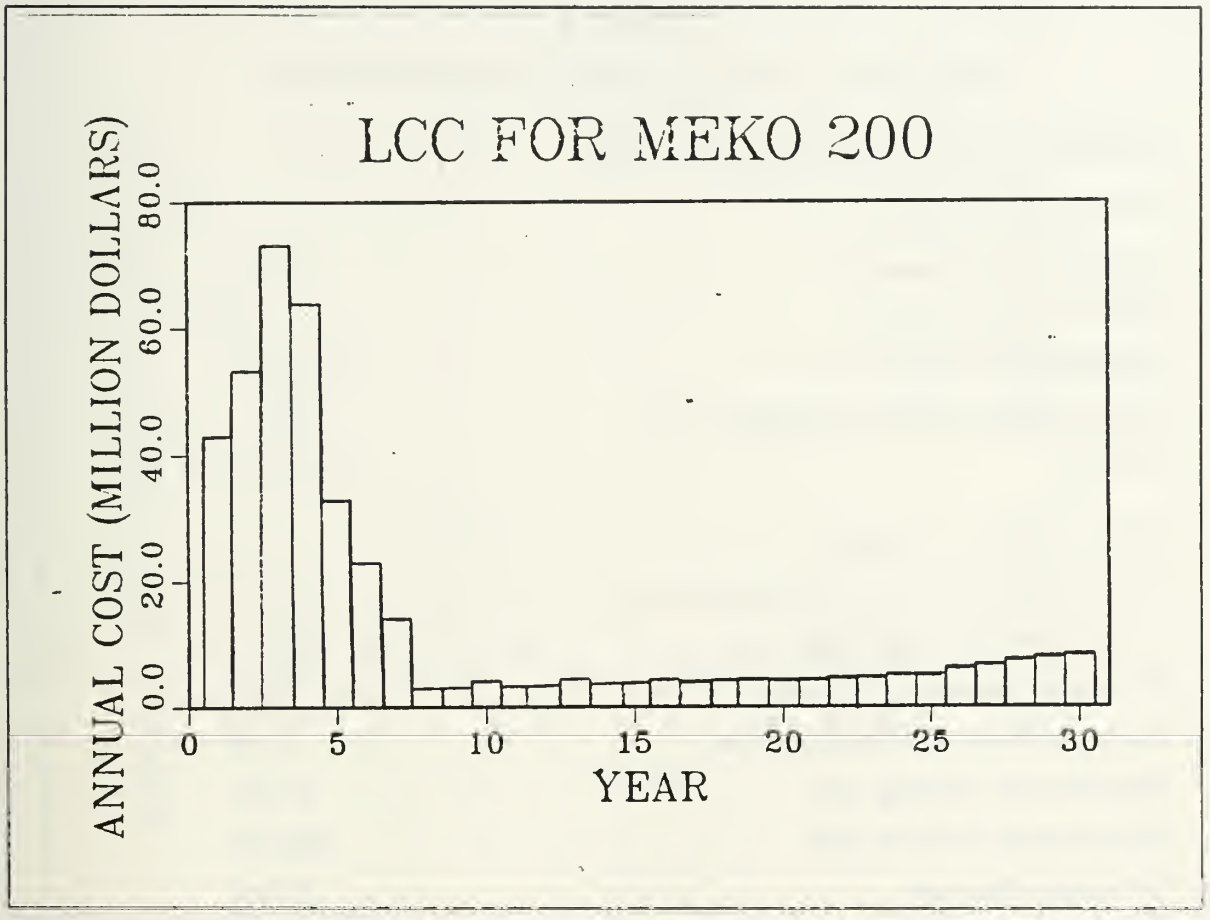


Figure 4.1 LCC for MEKO 200 class frigate.

Cost of spare and repair parts will be high. Because the lead time is long and long lead time needs high inventory level for spare and maintenance parts. Maintenance facilities cost is lower than the MEKO 200 class frigate's cost, because most of the preventative maintenance are accomplished by the operation personnel.

Maintenance cost is calculated by using same approach as it is in the annual cost calculation of MEKO 200 class frigates. Annual active operation time is assumed 2000 hours.

Based on these assumptions annual operation and maintenance cost of Perry class frigates is shown in Table 6.

In the calculation of LCC, we assumed that these frigates will have 30 year economic life. During this period they will not be modernized in order to increase their capabilities. In the comparsion of the LCC cost of these frigates we will use net present values of all expenses which occur during their operational life. Annual discount rate is assumed 8 per cent in the LCC calculation. Based on these assumptions the LCC of Perry class frigates is shown on shown in Figure 4.2.

TABLE 6

ANNUAL COST FOR PERRY CLASS FRIGATE

OPERATION & MAINTENANCE COST	
OPERATION COST	
Operation personnel cost	258,000
Operator training cost	153,300
Operational facilities cost	1,684,000
Support and handling equipment cost	145,700
TOTAL	2,241,000
MAINTENANCE COST	
Maintenance personnel and support cost	37,500
Cost of spare and repair parts	870,300
Test and support cost	21,500
Transportation and handling cost	8,700
Maintenance training cost	27,500
Maintenance facilities cost	525,750
Technical data cost	22,000
TOTAL	1,513,250
TOTAL OPERATION COST	3,754,250
THREE YEAR OVERHAUL COST	
Overhaul labor cost	307,000
Overhaul facilities cost	175,000
Overhaul material/spare part cost	1,090,000
TOTAL OVERHAUL COST	1,572,000

2. **Annual cost calculation for modernized destroyers**

Operation cost of these destroyer still higher than the annual operation cost of MEKO 200 and Perry class. Main reasons are high fuel consumption, low maintainability and lack of maintenance/spare parts. But operator training cost is lower.

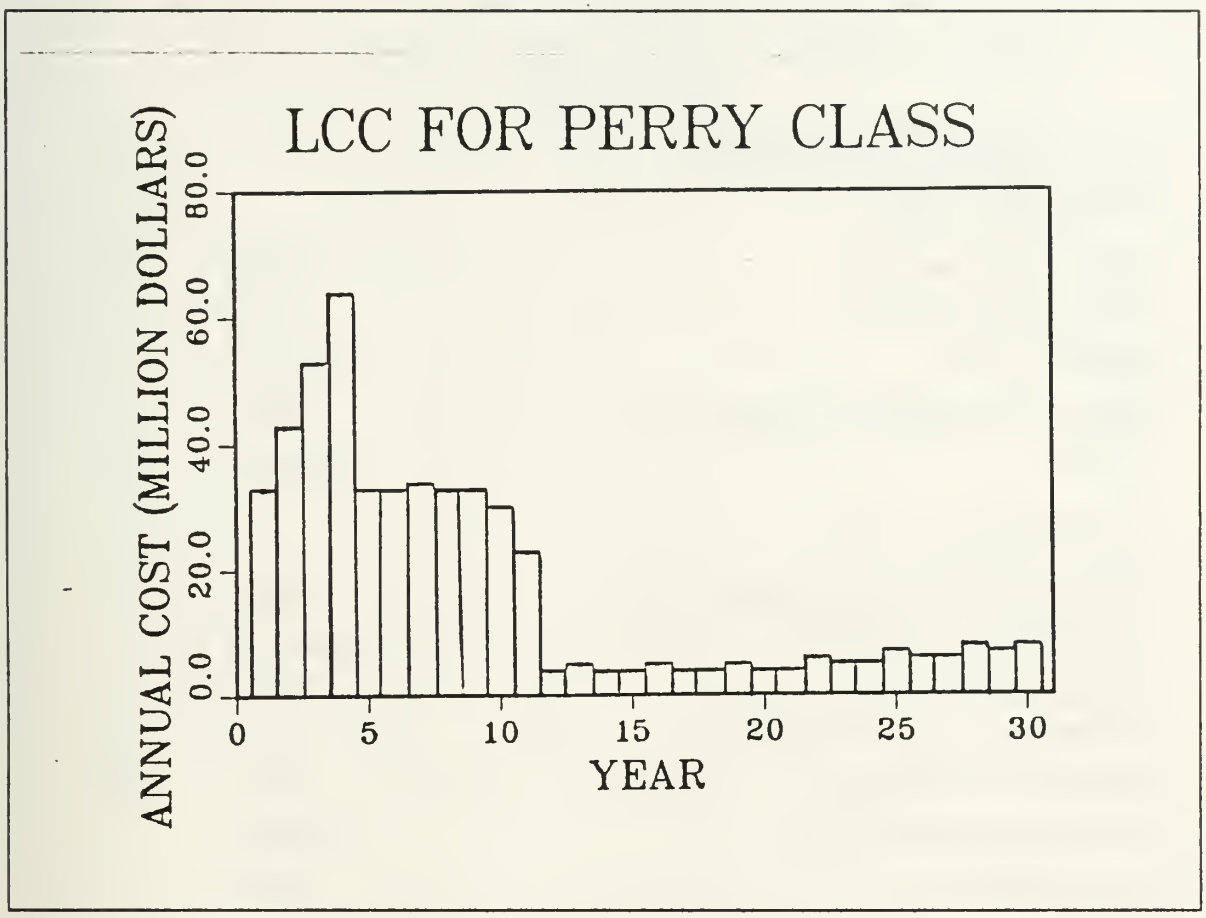


Figure 4.2 LCC for Perry Class Frigates.

In our operation cost calculation, we assumed that the active operation time will be 2200 hours for these destroyers. Because these destroyers need at least 3 hours time in order to leave from the main naval base when necessary. When these destroyers are responsible for emergency duty all the ship systems should be in operation during this period.

These destroyers have been in operation in Turkish Navy since 1970, but naval shipyards and maintenance support facilities don't have any record about their maintenance characterestics, like mean time between failure, mean time to repair, failure density function etc. We will use the data which obtained from the shipyard records for the future maintenance cost calculation.

Based on these assumptions annual operation and maintenance cost for the modernized carpenter class destroyer is shown in Table 7.

In the LCC calculation the economic life of modernized Carpenter class destroyer is assumed 15 years, and during this period there is no additional modernization. Annual inflation rate is assumed 8 per cent.

TABLE 7

ANNUAL COST FOR MODERNIZED CARPENTER CLASS DESTROYER

OPERATION & MAINTENANCE COST	
OPERATION COST	
Operation personnel cost	257,680
Operator training cost	30,350
Operational cost	1,993,890
Support and handling equipment cost	126,300
TOTAL	2,480,220
MAINTENANCE COST	
Maintenance personnel and support cost	126,300
Cost of spare and repair parts	868,400
Test and support cost	13,000
Transportation and handling cost	15,250
Maintenance training cost	8,700
Maintenance facilities cost	658,000
Technical data cost	2,600
TOTAL	1,692,250
TOTAL OPERATION COST	4,100,470
THREE YEAR OVERHAUL COST	
Overhaul labor cost	475,000
Overhaul facilities cost	210,000
Overhaul material/spare part cost	631,500
TOTAL OVERHAUL COST	1,316,500

Based on these assumptions LCC of modernized Carpenter class destroyer is shown on Figure 4.3.

3. **Annual cost calculation for Unmodernized destroyers**

These destroyers have the lowest annual operation cost among the four different type frigates/destroyers. Cost of spare and repair parts is lower than it is in

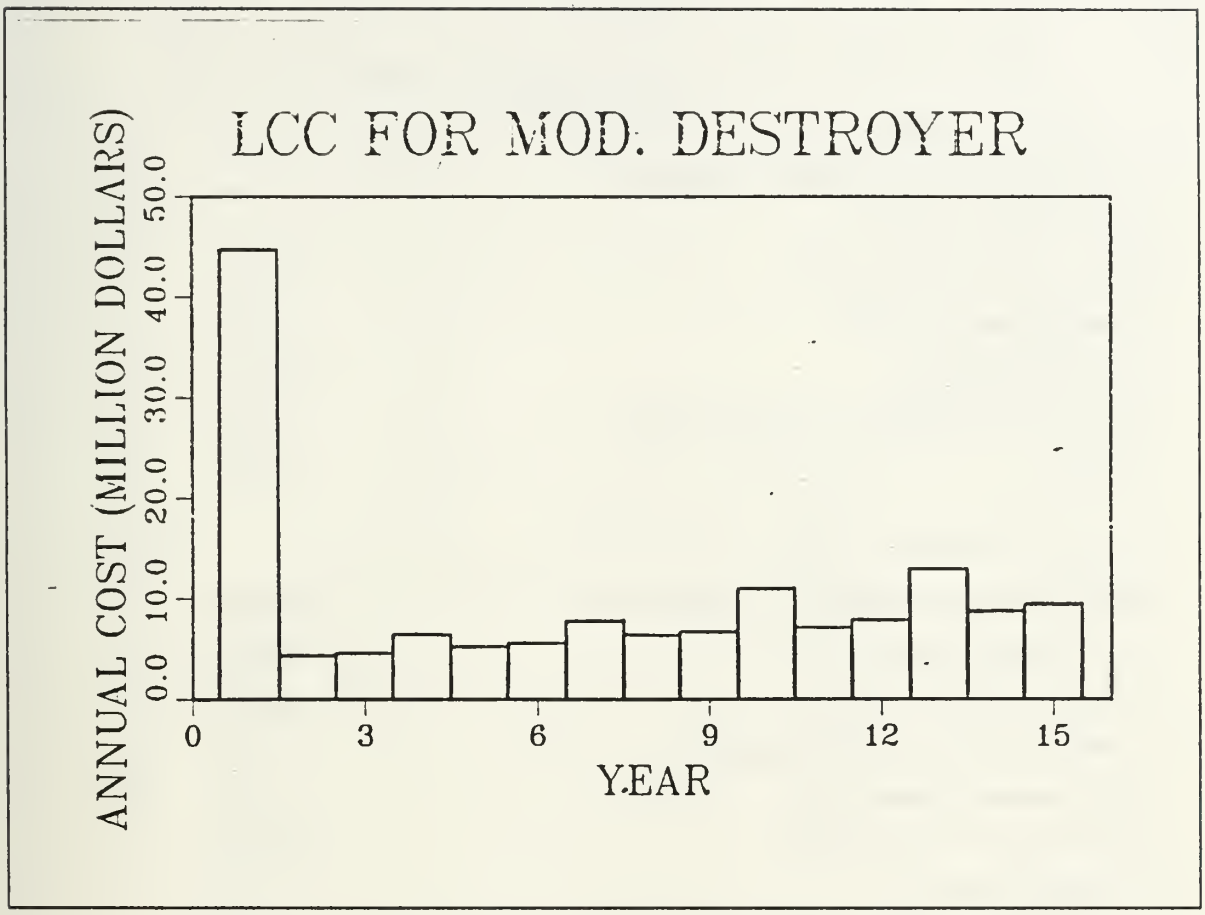


Figure 4.3 LCC for Modernized Carpenter Class Destroyer.

the cost calculation of the modernized Carpenter class destroyers. Because some of the present electronic support and ECM systems aren't in operation and there is no maintenance action for them.

Three year overhaul cost is higher than it is in the modernized Carpenter class destroyer cost calculation. These destroyers have not been overhauled effectively since their deployment date by the Turkish Navy. Especially main electricity power distribution system is in poor condition and their maintenance is expensive.

Annual active operation time is 2200 hours for these destroyers because of the same reason the modernized destroyers have. Maintenance personnel and maintenance facilities cost are calculated by using the data which were obtained from the past maintenance records.

Based on these assumptions annual operation and maintenance cost of these destroyers is shown in Table 8.

TABLE 8

ANNUAL COST FOR UNMODERNIZED GEARING CLASS DESTROYER

OPERATION MAINTENANCE COST	
OPERATION COST	
Operation personnel cost	258,000
Operator training cost	10,350
Operational cost	1,050,300
Support and handling equipment cost	52,600
TOTAL	1,371,250
MAINTENANCE COST	
Maintenance personnel and support cost	126,300
Cost of repair/spare parts	651,300
Test and support cost	8,500
Transportation and handling cost	15,250
Maintenance training cost	3,500
Maintenance facilities cost	723,800
Technical data cost	1,000
TOTAL MAINTENANCE COST	1,528,750
TOTAL OPERATION & MAINTENANCE COST	2,900,000
THREE YEAR OVERHAUL COST	
Overhaul labor cost	522,500
Overhaul facilities cost	231,000
Overhaul material and spare part cost	726,250
TOTAL OVERHAUL COST	1,479,750

We assumed that these destroyers will be in operation for 15 years in the Turkish Destroyer Fleet and during the this period there is no system modernization in order to increase their capabilities.

Based on these assumptions the LCC of the Gearing class destroyers is shown on Figure 4.4.

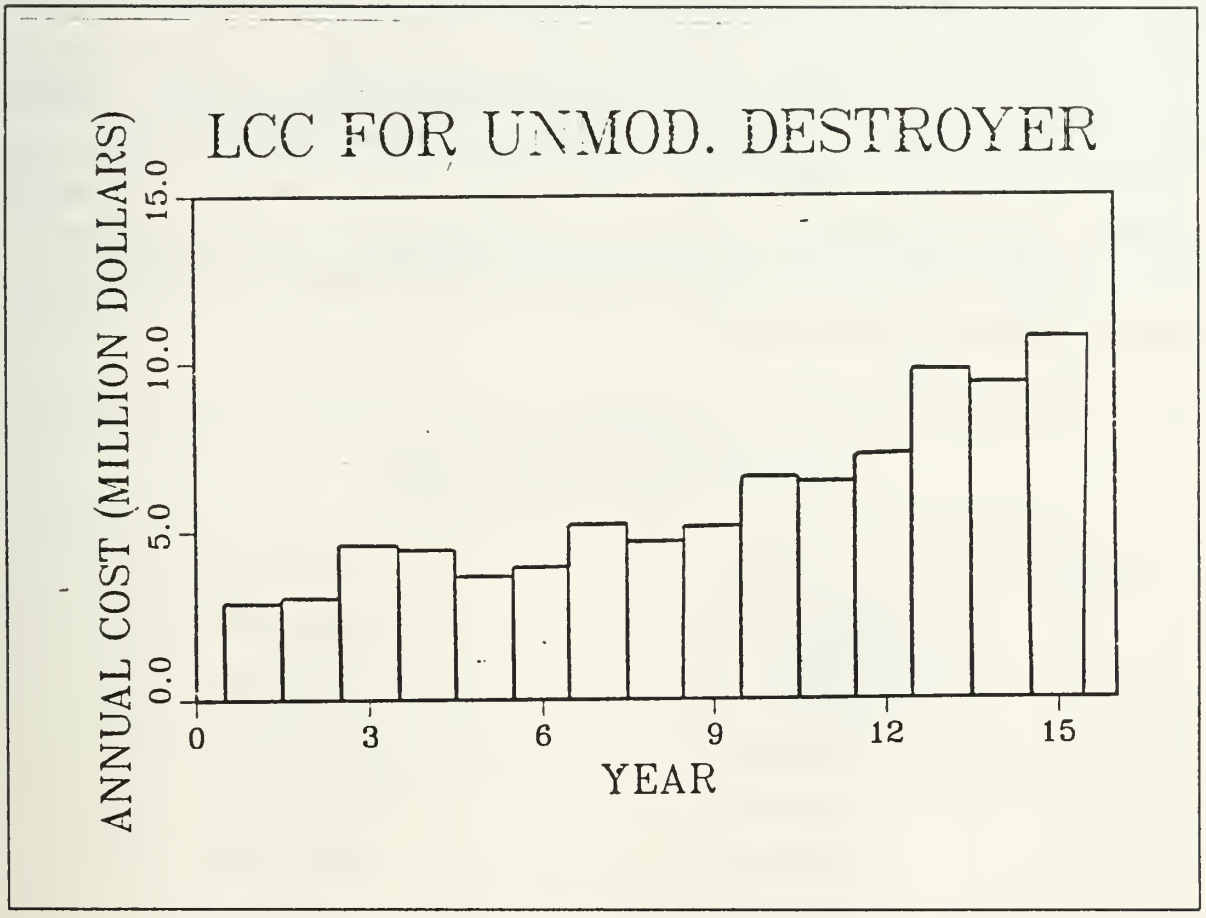


Figure 4.4 LCC for Unmodernized Gearing Class Destroyer.

4. **System Life-cycle Cost Calculation**

Present worth of the expenditure stream at a selected discount rate is one of the most important part of the system life-cycle cost calculation. It is appropriate where questions of the impact upon the national economy arise. In the Department of Defense, analysis do often subsequently test the sensitivity of decisions to various discount rates. The specific discount rate appropriate to Department of Defense studies is still being debated, with values from 5 per cent to 15 per cent typically being suggested. In our case we considered the discount rate as 8 per cent. [Ref. 11: p. 47]

The term "amortization" something a misnomer is analogous to the scrap value conception in equipment/system replacement studies. When systems are compared whose lifetime seem to differ widely, for example, when comparing ship systems whose useful lifetimes historically have been fifteen years, or considerably greater, with helicopter systems which have not seemed to have had this performance. The argument is that it is unfair to charge the shipsystem with the whole investment

cost if it will be useful for a considerable time beyond the "X" years considered in the study.

In our force life-cycle cost calculation the frigates/destroyers have different useful lifetimes. When modernized Carpenter and unmodernized Gearing class destroyers have 15 year useful lifetimes, new frigates have 30 year useful lifetimes in Turkish Navy. So we decided to calculate the force life-cycle cost for 15 year period. The value of the each force structure at the end of 15 year period is calculated by using sum of the digit amortization method.

TABLE 9
FORCE LCC CALCULATION

YEAR	FORCE I	FORCE II
1	261,627,000	294,645,000
2	289,807,700	331,849,600
3	351,640,300	417,638,500
4	317,707,000	317,085,300
5	159,358,700	181,546,700
6	163,461,000	145,871,200
7	191,297,300	130,363,600
8	171,689,300	73,319,000
9	177,013,600	78,605,700
10	109,988,000	116,639,950
11	155,743,300	88,563,300
12	105,525,000	97,639,800
13	119,345,700	112,961,500
14	128,743,000	124,658,900
15	162,564,400	144,818,350
TOTAL	2,865,503,300	2,656,206,100
Salvage Value	254,555,000	297,289,400
NPV of LCC	2,610,948,000	2,358,915,700

Costs which have already been incurred at the time an analysis is made are "sunk costs" and should not be included in the comparsion of the alternatives. We didn't

include the present value of the Carpenter, Gearing class destroyers in our life cycle cost calculation. In addition, the present value of the present maintenance facilities which are enough for the maintenance of the force structure II wasn't included while maintenance facilities cost was included in the life cycle cost calculation of the force structure I.

Based on these assumptions the life-cycle cost of each force structure is shown in Table 9.

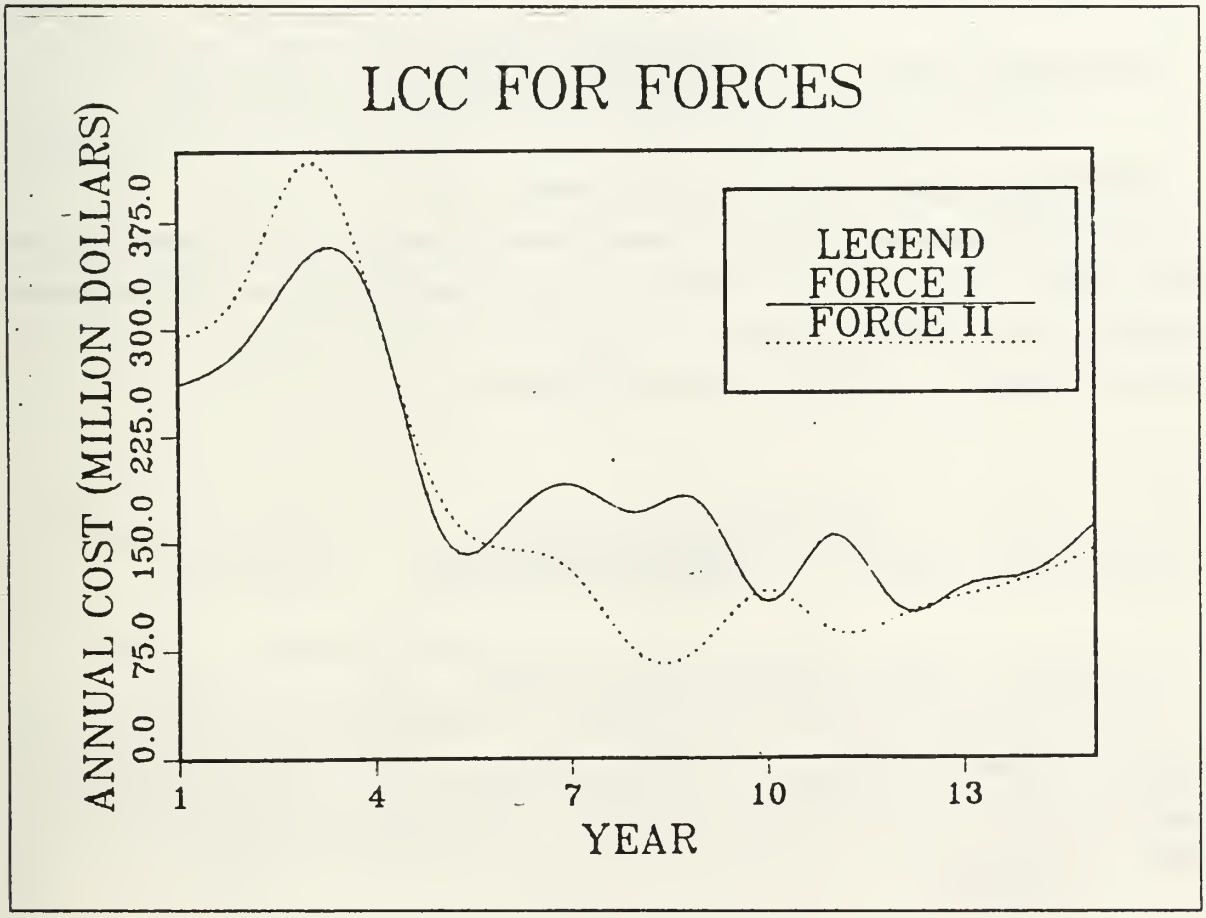


Figure 4.5 Force I and Force II Life-cycle Cost.

F. MEASUREMENT OF EFFECTIVENESS

The aspects of effectiveness can be quantified in terms of one or more figures of merit (FOMs), depending on the specific mission or system characteristics that one wishes to measure. Effectiveness must consider:

- System performance and physical parameters - capacity, range, accuracy, volume, speed, weight, and so on.

- System operational and support factors - availability, dependability, maintainability, supportability, and so on.
- Total life-cycle cost - research and development cost, production and construction cost, operation and maintenance cost, retirement and disposal cost, and so on.

[Ref. 13: p. 77]

Establishing a relationship between a performance or operational parameter and cost may constitute a desirable cost effectiveness FOM. In Turkish Destroyer Fleet case our FOMs are

$$\text{Effectiveness } FOM_{ssm} = \frac{\text{Force SSM Capacity}}{\text{System Life-cycle Cost}} \quad \text{(eqn 4.29)}$$

FOM_{ssm}= Figure of Merit for SSM capability

In the calculation of force SSM capacity, we only summed up the number of the SSM which are carried by the destroyers/frigates. Because in two different force structures all the destroyers/frigates are equipped with Harpoon missile system. The force SSM capacity calculation is shown on Appendix A.

$$\text{Effectiveness } FOM_{sam} = \frac{\text{Force SAM Capacity}}{\text{System Life-cycle Cost}} \quad \text{(eqn 4.30)}$$

FOM_{sam} = Figure of Merit for SAM capability

In the calculation of force SAM capacity, we followed the same procedure. All the SAM systems are Seasparrow air defense system in the two force structures, and there is no differance between their capabilities. The force SAM capacity calculation is shown on Appendix B.

$$\text{Effectiveness } FOM_{air} = \frac{\text{ForceAir Radar coverage}}{\text{System Life-cycle Cost}} \quad \text{(eqn 4.31)}$$

FOM_{air} = Figure of Merit for air search capability

One of the most important duty of this fleet is to accomplish early air detection of enemy aircrafts in the operational field. Both two force structure have enough air

search capability in order to cover all the Turkish coast along the Black sea, Aegean sea and Mediterranean sea with the help of ground radar bases. We measured air radar coverage capacity in terms of squarekilometers. The calculation of force air search is shown on Appendix C.

$$\text{Effectiveness } FOM_{lrg} = \frac{\text{Force Long Range Gun Power}}{\text{System Life-cycle Cost}} \qquad \text{(eqn 4.32)}$$

FOM_{lrg} = Figure of Merit for long range gun power

This effectiveness measurement is the hardest one to measure. There are three different types long range gun in two different force structures.

In order to be able to compare their fire power we used weighted quantitative method for each type of long range gun. The force long range gun power calculation is shown on Appendix D. [Ref. 14: p. 97]

$$\text{Effectiveness } FOM_{adg} = \frac{\text{Force short range Gun Power}}{\text{System Life-cycle Cost}} \qquad \text{(eqn 4.33)}$$

FOM_{adg} = Figure of Merit for air defense gun power

The number of the active firing is the most important aspect of the short range missile/aircraft defense system. We didn't take into account the firing rate and max range of the different gun types. Our calculation includes the number of firing which can be accomplished by using ready ammunition when the target is in their firing range. The calculation of force air defense gun power is shown on Appendix E.

The values of the FOMs are as in Table 10.

TABLE 10
VALUES OF THE FOMS

FOM	Force I	ForceII
FOM_{ssm}	1.99×10^{-8}	3.05×10^{-8}
FOM_{sam}	7.2×10^{-8}	5.93×10^{-8}
FOM_{air}	1.286×10^{-3}	1.128×10^{-3}
FOM_{lrg}	1.43×10^{-4}	1.655×10^{-4}
FOM_{adg}	5.75×10^{-6}	10.77×10^{-6}

V. CONCLUSION

In general, economic analysis/program evaluation will be used by managers as an input in selecting the most cost effective alternative. As a rule, the best criterion, in cases where benefits and outputs are a determining factor, is to prefer that alternative which yields the greatest benefits or effectiveness for a given level of cost (discounted). In situations where it is difficult to quantify benefits and measures of effectiveness, it is important to provide as much useful information as possible to enable a decision to be made as to which alternative yields the most benefits or effectiveness. Where special considerations require selection of other than the cost effective alternative, these considerations must be compelling and defensible. [Ref. 15: p. 12-13]

Selection of the best system among the competing alternatives is the hardest step for the decision maker. As an example, in our case, the decision maker may select force structure II over force structure I because it has higher cost effectiveness on SSM, long range gun power and short range air defense gun power which are necessary for offensive surface operation. On the other hand he may think that industrial support, training of enlisted men, maintenance of shipsystems are easier in force structure II. Or the decision maker may select force structure I over force structure II because the air search capability and SAM capability of force structure I which are necessary for defensive operation are better than force structure II. In addition, he may think that changing the type of vessels may create unacceptable logistics problem in future.

In defense decision making process, the decision maker is influenced by the political situation and economic situation as well as the combat needs of the naval forces. Because of these reasons the best alternative isn't so obvious in our case, and rarely in other cases. But these outputs will help to the decision maker in his decision making process.

APPENDIX A
FORCE SSM POWER CALCULATION

TABLE 11

FORCE I SSM POWER

Type of destroyers/frigates	Number of destroyes/frigates	Number of missiles on the ship	Total
Perry Class	3	4	12
Modernized destroyer	5	8	40
Total Force SSM power			52

TABLE 12

FORCE II SSM POWER

Type of destroyer/frigate	Number of destroyer/frigate	Number of missiles on the ship	Total
MEKO 200	4	8	32
Modernized destroyer	5	8	40
Total force SAM capacity			72

APPENDIX B
FORCE SAM POWER CALCULATION

TABLE 13

FORCE I SAM POWER

Type of destroyers/frigates	Number of destroyers/frigates	Number of missiles on the ship	Total
Perry class	3	36	108
Modernized destroyer	4	20	80
Total Force SAM power			188

TABLE 14

FORCE II SAM POWER

Type of destroyers/frigates	Number of destroyers/frigates	Number of missiles on the ship	Total
MEKO 200	4	20	80
Modernized destroyer	3	20	60
Total Force SAM Power			140

APPENDIX C
FORCE AIR RADAR COVERAGE

TABLE 15

FORCE I AIR RADAR COVERAGE

Type of air search radar	Number of radar	Air search capacity	Total (km^2)
AN SPS 48	3	321,526	964,578
AN SPS 40	4	321,526	1,286,144
AN SPS 29	8	138,474	1,107,792
Total force air coverage			3,357,544

TABLE 16

FORCE II AIR RADAR COVERAGE

Type of air search radar	Number of radar	Air search capacity	Total (km^2)
DA 8 APS 49	4	101,736	406,944
AN SPS 40	4	321,526	1,286,144
AN SPS 29	7	138,474	969,318
Total Force air radar coverage			2,262,406

APPENDIX D
FORCE LONG RANGE GUN POWER

TABLE 17

FORCE I LONG RANGE GUN POWER

Type of long range gun	Number of barrel	Rate of fire	Weighted score each firing	Total score
OTO MELERA	3	80	136	32,640
5″/38″ gun	54	20	316	341,288
Total long range gun power				373,920

TABLE 18

FORCE II LONG RANGE GUN POWER

Type of long range gun	Number of barrels	Rate of fire	Weighted score each firing	Total score
5″/56″ Mk 45	4	25	426	42,600
5″/38″ gun	50	316	348,000	
Total long range gun power				390,600

APPENDIX E
FORCE SHORT RANGE GUN POWER

TABLE 19

FORCE I SHORT RANGE GUN POWER

Type of short range gun	Number of guns	Number of firings	Total
PHALANAX	3	3,000	9000
35 mm Oerlikon	12	360	4,320
40 mm Bofors	18	80	1,440
Total force short range gun power			14,760

TABLE 20

FORCE II SHORT RANGE GUN POWER

Type of short range gun	Number of guns	Number of firings	Total
Sea Guard	12	1,660	19,920
35 mm Oerlikon	11	360	3,960
40 mm Bofors	16	80	1,520
Total Force shorte range gun power			25,400

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